An Overview of the Hudson Bay Marine Ecosystem

D.B. Stewart[1] and W.L. Lockhart[2]

Central and Arctic Region
Fisheries and Oceans Canada
Winnipeg, Manitoba R3T 2N6

[1] Arctic Biological Consultants, 95 Turnbull Drive, Winnipeg, MB, R3V 1X2.
[2] 833 Harstone Road, Winnipeg MB, R3R 1E1.

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[1] Arctic Biological Consultants, 95 Turnbull Drive, Winnipeg, MB, R3V 1X2.
[2] 833 Harstone Road, Winnipeg MB, R3R 1E1.

PREFACE

This report was prepared under contract for Fisheries and Oceans Canada, Central and Arctic Region, Winnipeg, MB. The Scientific Authorities for this contract were Don Cobb and Steve Newton.

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ABSTRACT

Stewart, D.B., and Lockhart, W.L. 2005. An overview of the Hudson Bay marine ecosystem. Can. Tech. Rep. Fish. Aquat. Sci. 2586: vi + 487 p.

This overview summarizes knowledge of the Hudson Bay marine ecosystem, including James Bay. It has three main objectives: 1) to establish what is known about the region; 2) to provide historical (temporal) and geographical (spatial) perspective; and 3) to establish linkages among people of different cultural backgrounds and disciplines. Interactions among the ecosystem's physical, chemical, and biological components are discussed, as are factors that stress the ecosystem such as harvesting, development activities, contaminants, and climate change. The limits of our knowledge are established. The importance of key aspects of the Hudson Bay ecosystem, and their connections and interactions, are discussed. The depth of coverage varies with the information available and its relevance.

Historical information, traditional knowledge, and scientific data have been used in the overview. They are complementary sources of information that are often in good agreement. Each source has strengths and weaknesses: historical information can be limited to archival documents; traditional knowledge relies on the experience and memory of a small population that is scattered along a very long, often inhospitable, coastline; and research has been limited by cost and logistical constraints. Where differences in conclusions exist, they are highlighted and explained whenever possible.

Key Words: Canada subarctic; James Bay; Hudson Bay; Roes Welcome Sound; Repulse Bay; Hudson Strait; Quebec; Ontario; Manitoba; Nunavut; Kivalliq; Nunavik; Belcher Islands; Inuit; Cree; geology; physiography; climate; oceanography; Arctic waters; hydrology; ecology; plants; invertebrates; fish; marine mammals; birds; history; human settlement; parks; protected areas; sensitive habitat; harvesting; renewable resource use; economic development; environmental impact; marine ecosystem; non-renewable resource use; hydroelectric development; sediment metals; contaminants; mercury; climate change.

RÉSUMÉ

Stewart, D.B., and Lockhart, W.L. 2005. An overview of the Hudson Bay marine ecosystem. Can. Tech. Rep. Fish. Aquat. Sci. 2586: vi + 487 p.

Le présent document est un résumé des connaissances sur l'écosystème marin de la baie d'Hudson, y compris la baie James. Il vise les trois objectifs suivants : 1) faire un bilan des connaissances sur la région; 2) donner une perspective historique (temporelle) et géographique (spatiale); et 3) établir des liens entre les gens de spécialités et d'antécédents culturels différents. Les interactions entre les éléments physiques, chimiques et biologiques de l'écosystème sont discutées, ainsi que les facteurs qui l'agresse, comme la chasse et la pêche, les activités de développement, les contaminants et le changement climatique. Les limites de nos connaissance sont en outre établies. L'importance d'aspects clés de l'écosystème de la baie d'Hudson, et des liens et des interactions entre eux, sont discutés. L'étendue de la couverture varie selon les renseignements disponibles et leur pertinence.

Ce survol repose sur des renseignements historiques, des connaissances traditionnelles et des données scientifiques. Ce sont des sources complémentaires d'information qui montrent souvent un niveau de concordance élevé, quoique chacune ait des atouts et des faiblesses. Les renseignements historiques peuvent n'être que des documents d'archives, les connaissances traditionnelles se fondent sur l'expérience et la mémoire d'une petite population dispersée le long d'un très vaste littoral, souvent inhospitalier, alors que les recherches sont limitées en raison des coûts et des contraintes logistiques. Lorsque des conclusions différentes sont formulées, elles sont mises en lumière et expliquées dans la mesure du possible.

Mots clés : zone subarctique du Canada; baie James; baie d'Hudson; détroit de Roes Welcome; Repulse Bay; détroit d'Hudson; Québec; Ontario; Manitoba; Nunavut; Kivalliq; Nunavik; îles Belcher; Inuit; Cri; géologie; physiographie; climat; océanographie; eaux arctiques; hydrologie; écologie; plantes; invertébrés; poissons; mammifères marins; oiseaux; histoire; établissement humain; parcs; aires protégées; habitat sensible; chasse; pêche; utilisation de ressources renouvelables; développement économique; incidences environnementales; écosystème marin; utilisation de ressources non renouvelables; aménagement hydroélectrique; métaux dans les sédiments; contaminants; mercure; changement climatique.

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This work benefited from the assistance and expertise of many people. Don Cobb, Helen Fast, and Steve Newton had the vision to initiate this project, oversaw it as part of the Department of Fisheries and Oceans' (DFO) coastal zone management initiatives in Hudson Bay, and helped to see it through to publication.

Lionel Bernier and the late Dr. Max Dunbar contributed to earlier overview documents that were prepared to assist Parks Canada identify possible National Marine Parks in Hudson Bay and James Bay. These documents, prepared in the early 1990s for Francine Mercier and Claude Mondor, formed the basis of this work. The widely distributed sediment data for Hudson Bay were derived from the Ph.D. Thesis of Penny Henderson of the Geological Survey of Canada.

Elva Simundsson and her staff at the Eric Marshall Aquatic Research Library (DFO, Winnipeg) provided invaluable assistance in obtaining reference material. Ken Abraham of the Ontario Ministry of Natural Resources (OMNR), Danielle Baillargeon (DFO), Chris Chenier (OMNR), Brigitte de March (DFO), Miriam Fleming (Sanikiluaq), Patt Hall (DFO), Penny Henderson of the Geological Survey of Canada, Ipeelee Itorcheak (DFO), Craig Machtans of Environment Canada (EC), Martin Obbard (OMNR), Richard Remnant of North/South Consultants Inc. in Winnipeg, Pierre Richard (DFO), François Saucier (DFO), Lyle Walton (OMNR), and Brian Zawadski (Nunavut Development Corp., Rankin Inlet) kindly provided unpublished data for use in this report. Dave Rudkin of the Royal Ontario Museum and Graham Young of the Manitoba Museum (MM) kindly allowed us to use their photographs, and Martin Curtis (DFO) confirmed the identification of the invertebrate species they show. Together with many, many others they also provided published information and sound advice.

Sections of the manuscript were edited by Ross Brown (EC; climate), Don Cobb (DFO; introduction, invertebrates), Susan Cosens (DFO; mammals), Helen Fast (DFO; human occupation), Patt Hall (DFO; harvesting), Heiner Josenhans (Geological Survey of Canada; geology), Pierre Larouche (DFO; oceanography), Robie Macdonald (DFO; climate change), Mark Mallory (Canadian Wildlife Service; birds), Dale McGowan (DFO; harvesting), Steve Newton (DFO; economic development, protected areas and sensitive habitats), Simon Prinsenberg (DFO, oceanography), David Punter of the University of Manitoba (UM; plants), James Reist (DFO; fishes), Pierre Richard (DFO; mammals), Gordon Robinson (UM; plants), Gary Stern (DFO; contaminants), Rob Stewart (DFO; mammals), and Graham Young (Manitoba Museum; geology).

Barb Stewart (Sila Consultants, Howden, MB) edited the entire manuscript, and Cecile Stewart (Arctic Biological Consultants, Winnipeg) provided editorial comments throughout this project. Mark Ouellette (DFO) formatted the manuscript for publication and prepared many of the maps. Steve Newton prepared the cover page.

We thank all of you for your efforts, which have greatly improved this work and helped to bring it to fruition.

DEDICATION

This work is dedicated to Cécile, Ceilidh, and Heather Stewart, whose love and understanding made it possible.

1.0 INTRODUCTION

Under the *Oceans Act*, the Department of Fisheries and Oceans (DFO) has a mandate to lead and facilitate in the Integrated Management of Canada's estuarine, coastal and marine environments. To accomplish this, DFO plans to take an ecosystem-based approach to ocean management and to coordinate policies and programs across levels of government. Improved understanding and protection of the marine environment are key aspects of this program. Ecosystem-based management involves, in particular, a shift in research and management from the traditional single species approach to a more holistic approach, which emphasizes an understanding of the individual species, including humans, as a function of the ecosystem. The aim is to provide a clearer understanding of the way the different parts of the ecosystem interact with each other and their environment.

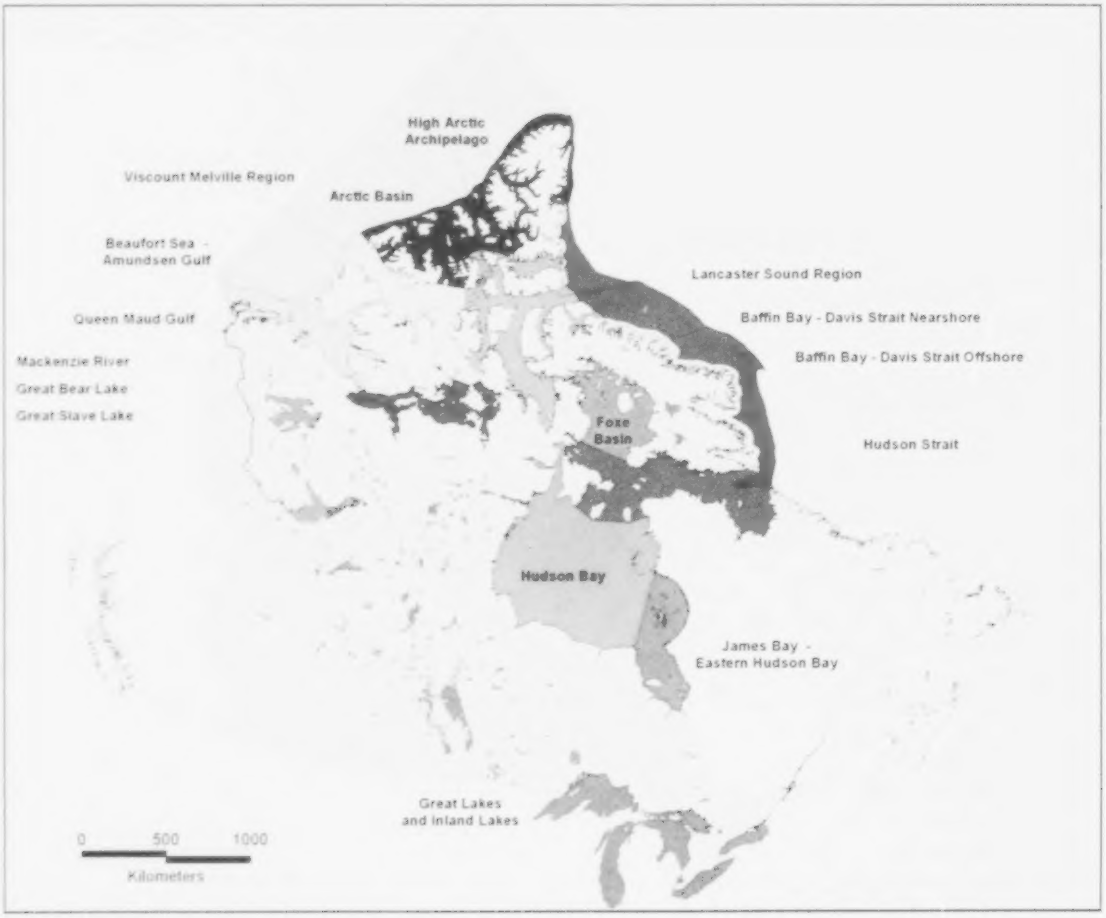

Figure 1-1. **Marine ecoregions in Arctic Canada identified and under discussion by the Department of Fisheries and Oceans from an Arctic science planning workshop in 2000 (D. Cobb, DFO Winnipeg, pers. comm.).**

The Central and Arctic Region of DFO, which manages marine environments in Arctic Canada, has tentatively identified eleven ocean management areas in the Canadian Arctic (Figure 1-1; D. Cobb, DFO, Winnipeg, pers. comm.). This overview of the Hudson Bay marine ecosystem, which includes both the Hudson Bay and James Bay/Eastern Hudson Bay regions (Figure 1-2), was prepared to support the Department's coastal

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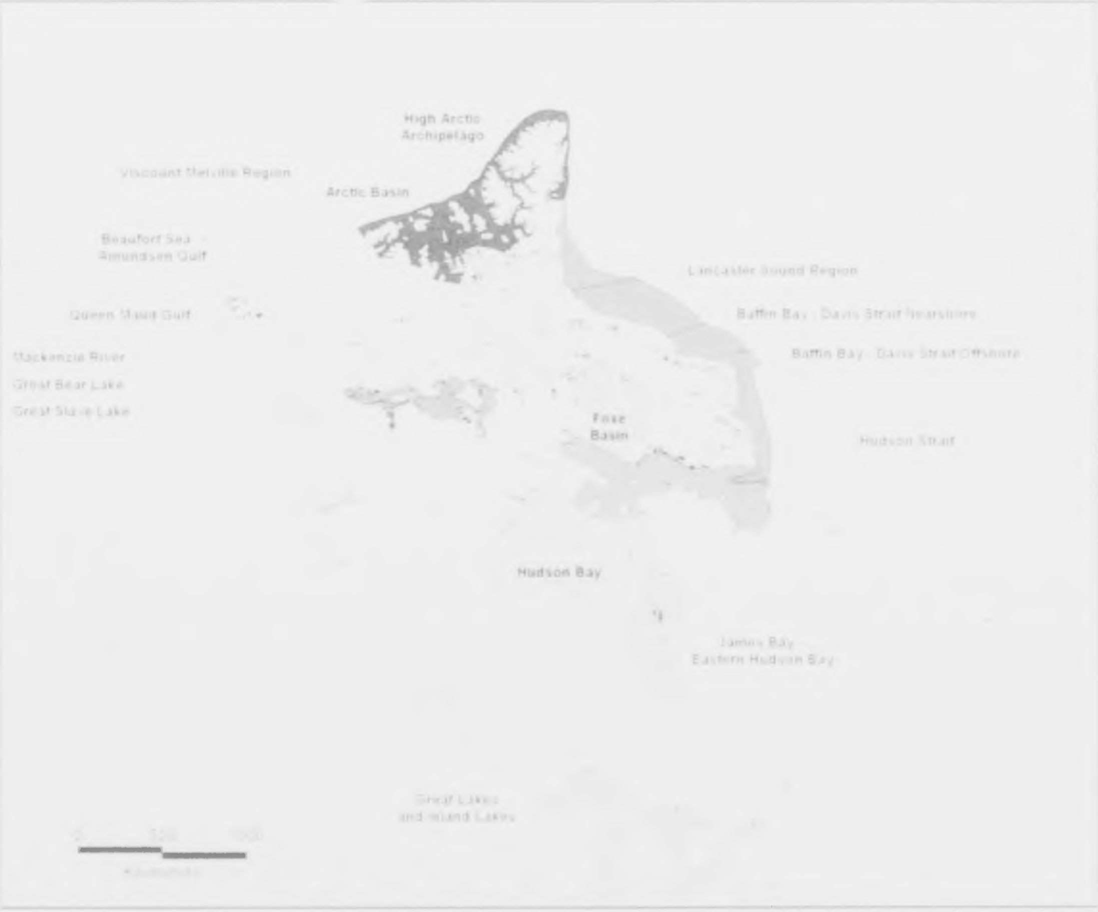

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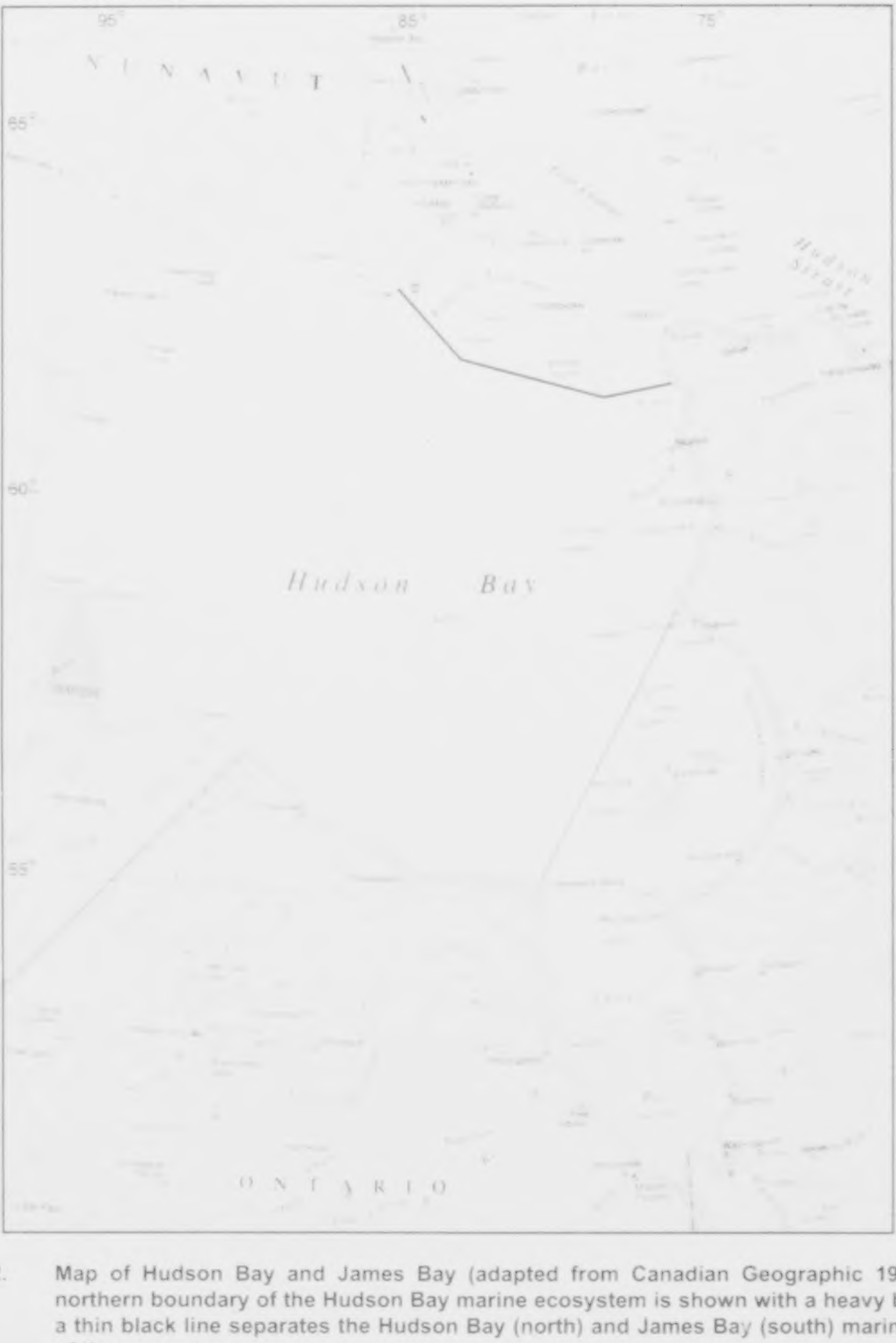

Figure 1-2. Map of Hudson Bay and James Bay (adapted from Canadian Geographic 1999). The northern boundary of the Hudson Bay marine ecosystem is shown with a heavy black line; a thin black line separates the Hudson Bay (north) and James Bay (south) marine regions of the ecosystem.

2.0 ECOLOGICAL OVERVIEW

The Hudson Bay marine ecosystem extends over a very large geographical area. It includes James Bay and Hudson Bay and is bounded in the east by the coast of Québec, in the south by Ontario and Manitoba, and in the west by Nunavut. Its northern marine boundary has been set arbitrarily as a line that extends from Cap Aiviriuvik, Québec (61°41'N, 77°58'W) to Cape Low, Southampton Island, via the southern tips of Mansel and Coats Island, and from Cape Welsford on Southampton Island to Cape Clarke on the Nunavut mainland via White Island (Figure 2-1). The ecosystem receives Arctic marine water from Foxe Basin and freshwater runoff from a catchment basin that is larger than those of the Mackenzie and St. Lawrence rivers combined (Figure 2-1). Because of its large extent, the ecosystem spans many different coastal ecozones. It offers a broad and varied range of habitats that are used year-round by a range of Arctic and Subarctic biota, and seasonally by many migratory fishes, marine mammals and birds.

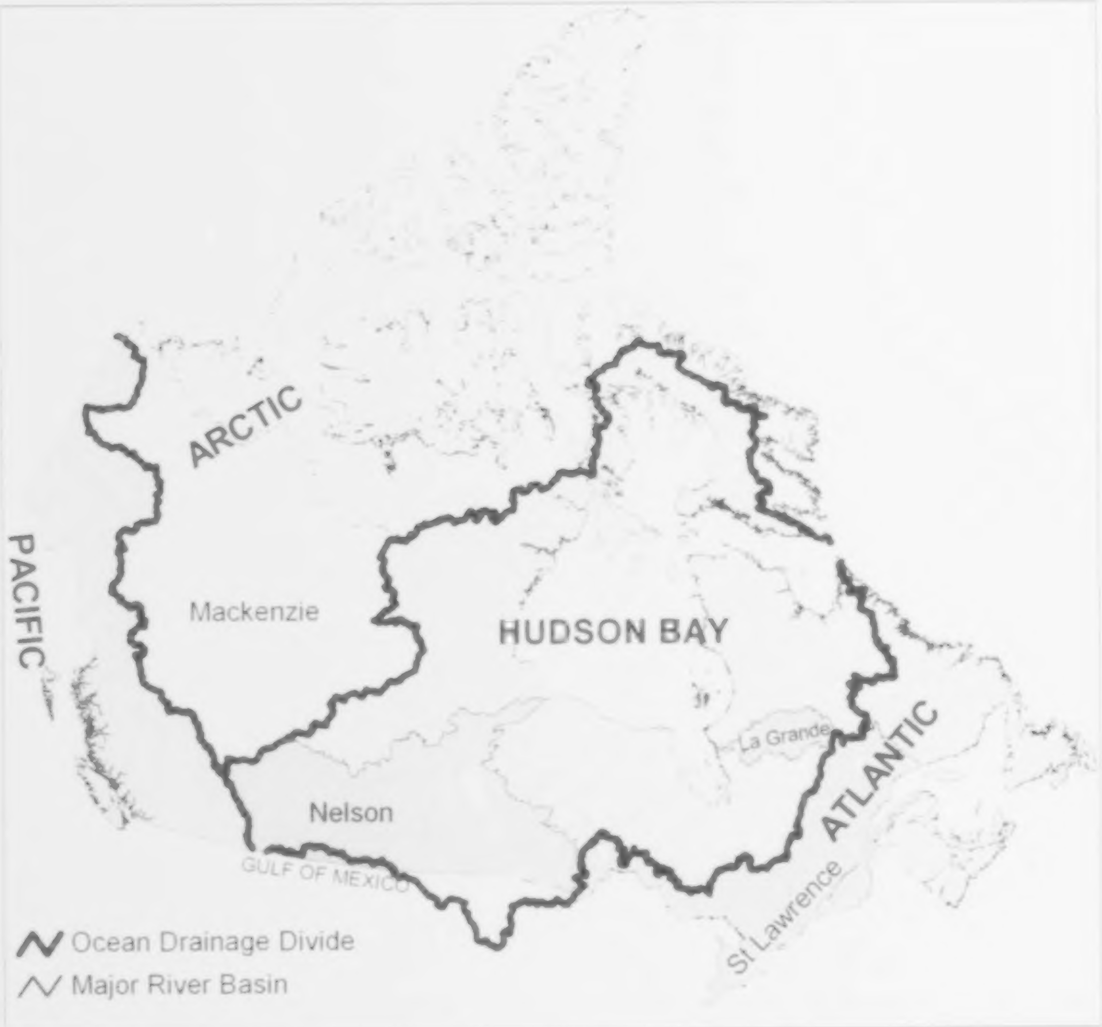

Figure 2-1. Hudson Bay watershed.

Three key features characterize the Hudson Bay marine ecosystem (Stewart 2000). The first of these is the extreme southerly penetration of Arctic marine water, which enables polar bear to live and breed in southern James Bay at the same latitude as the holiday resorts in Jasper, Alberta. Second is the very large volume of freshwater runoff that enters it from the land--each year James Bay has a net gain of freshwater that, spread over its entire surface, would form a layer 4.73 m thick (Prinsenberg 1986a). And third, is the dynamic geomorphology of the coastal zone, which is still rebounding from the great weight of the Laurentide Ice Sheet that covered the entire area. New land is emerging from the sea at a rate of up to 15 horizontal m per year along the stretch of low-lying, marshy coast with its wide tidal flats that continues almost uninterrupted from the Conn River in Québec to Arviat in Nunavut (d'Anglejan 1980; Martini 1982).

Each of these key aspects of the ecosystem creates critically important seasonal habitat for large concentrations of internationally important migratory species. The sea ice supports seals upon which polar bears depend; literally millions of geese and shorebirds feed and/or breed in the vast coastal salt marshes; productive eelgrass (*Zostera marina* L.) beds provide food for multitudes of waterfowl on their way to and from breeding habitat in the Arctic Islands; and the large estuaries provide vital habitat for anadromous fishes and beluga whales. Indeed, the number of belugas in the area of the Nelson River estuary on 19 July 1987 was estimated at 19,500 animals (Richard et al 1990)! This is the largest single concentration of belugas in the world. While the key aspects of the Hudson Bay environment are interesting, the habitats they create are unique and irreplaceable.

The overview that follows describes the Hudson Bay marine ecosystem and how it interacts with its surroundings. It is based on existing knowledge and progresses from the physical to the biological, and finally to the human features of the ecosystem. The overview is an update of two earlier reviews of the region's marine ecology prepared by Stewart et al. (1991, 1993). Geological and climatic forces that have shaped and continue to influence the Hudson Bay basin will be discussed first, then oceanography within the basin, and finally use of coastal and marine habitats by biota including humans.

3.0 GEOLOGY AND PHYSIOGRAPHY

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Aspects of the geology, glaciation, coastal features, and seafloor that are important to the character of the marine ecosystem are described in this section. Complex details of the geological substructure and successive glaciations add little to our understanding of the marine ecology and will not be discussed.

Compiled papers in the following volumes: Science, History and Hudson Bay (Beals and Shenstone [ed.] 1968), Earth Sciences Symposium on Hudson Bay (Hood [ed.] 1969), Scientific Studies on Hudson and James Bays (Martini [ed.] 1982), Canadian Inland Seas (Martini [ed.] 1986a), Quaternary Geology of Canada and Greenland (Fulton [ed.] 1989) and Sedimentary Cover of the Craton in Canada (Stott and Aitken [ed.] 1993), provide a starting point for those seeking more detailed information on regional geology and glaciations.

3.1 GEOLOGY

The rock basin that holds Hudson and James bays was formed over a very long time by various geological processes. It is situated in an area that has been depressed relative to the surrounding shield regions since at least late Palaeozoic time (Coles and Haines 1982) and consists of portions of three of Canada's geological provinces (Figure 3-1). These provinces, the Superior and Churchill provinces of the Canadian Precambrian Shield and the Hudson Platform, are distinguished from one another on the basis of the age, composition and structure of their rock strata. The older Shield rock is crystalline and often intensely deformed while the younger carbonate-dominated sedimentary rock of the Hudson Platform is mostly flat lying. These rocks form the bedrock that underlies the loose surface materials in different areas of the basin. Their composition and structure are a major determinant of the coastal physiography, surface soil and offshore sediment, bathymetry, and local physical and biological oceanography of the Hudson Bay marine ecosystem.

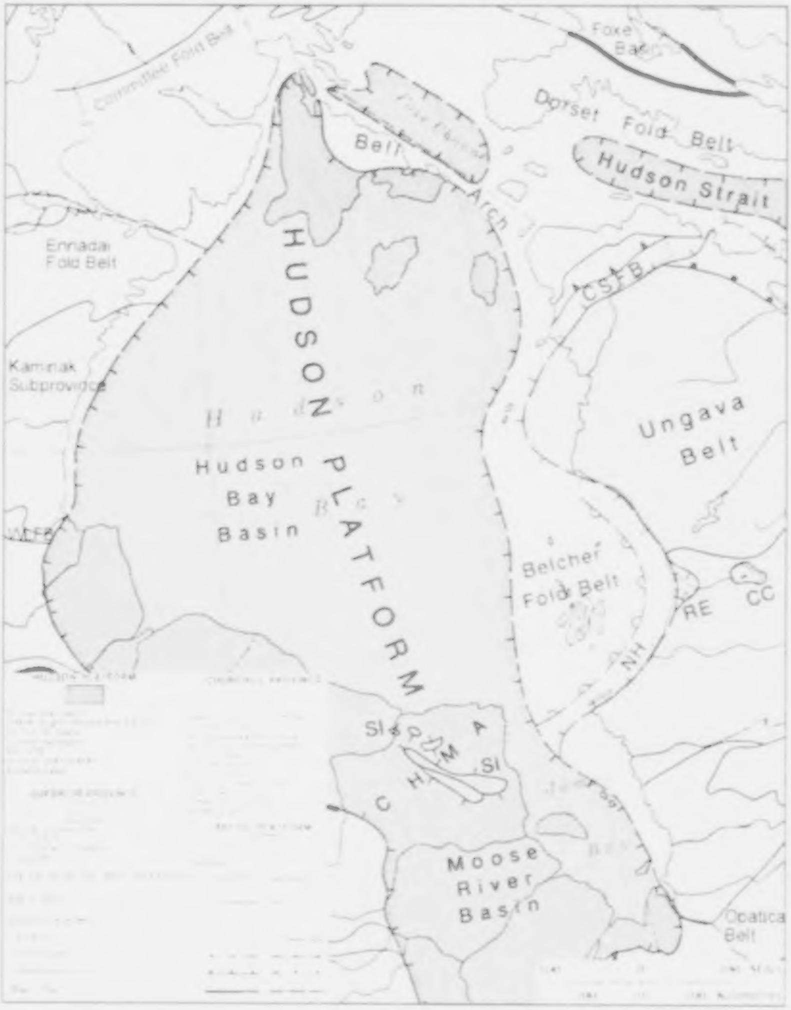

Figure 3-1 Geological Provinces and lithology (from Douglas 1973).

The crystalline rock of the Superior Province formed first and underlies the entire basin (Whitmore and Liberty 1968; Bostock 1969; Douglas 1972, 1973; Brooks 1980; Donaldson 1986; Mortensen and Ciesielski 1987). It constitutes the bedrock of the Québec coast south of Korak Bay, except in the area of Richmond Gulf (Lac Guillaume Delisle) and west of the Nottaway River, and the bedrock beneath the eastern half of James Bay. Elsewhere in the basin it forms a sialic crust beneath the younger sedimentary, metamorphic and volcanic rock of the Churchill Province and the sedimentary rocks of the Hudson Platform. North of Rivière de Castor the rock of the Superior Province forms plutonic belts, to the south basement (Figure 3-1). The plutonic rock is mainly intensely deformed and metamorphosed migmatic and granitic gneiss including undifferentiated older and younger rocks, and granulites; the basement rock is mainly deformed and/or isotopic age modified migmatic and granitic gneiss and undifferentiated older and younger rocks. These rocks formed during the Archaean eon, 4000-2500 million years before present (MYBP).

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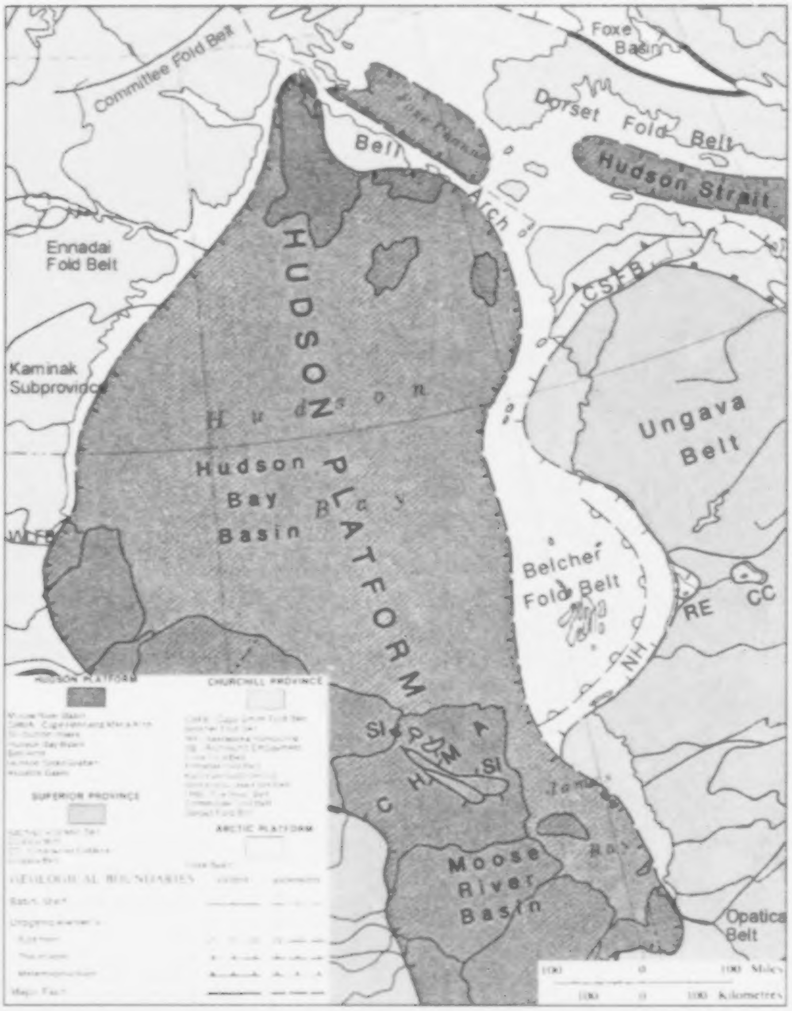

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Younger crystalline rock of the Churchill Province overlies the older rock of the Superior Province throughout much of the basin. It constitutes the bedrock of the Québec coast north of Korak Bay and in the Richmond Gulf area; the Ottawa, Belcher and Nastapoca islands; the west coast of Hudson Bay north of the Knife Delta (58°54'12"N, 94°41'52"W) in Manitoba; and the bedrock under the coastal waters in these areas, including most of southeastern Hudson Bay. There are exposed meetings of the Superior and Churchill provinces at the margins of the Cape Smith Fold Belt and Richmond Gulf Embayment. Unlike the Superior Province, the volcanic-sedimentary associations in the Churchill Province occur in linear and curvilinear fold belts in which the sedimentary rocks are generally more abundant than are the volcanic rocks (Donaldson 1986).

The Churchill Province consists mainly of basement rocks of Proterozoic age (Aphebian Era 2450-1700 MYBP), including deformed and/or isotopic age modified migmatic and granitic gneiss and undifferentiated older and younger rocks, except in the Cape Smith Fold Belt and Kaminak Subprovince (Whitmore and Liberty 1968; Taylor 1982; Aylsworth et al. 1986; Donaldson 1986). The Cape Smith Fold Belt extends northeastward from the Ottawa Islands (Coles and Haines 1982) to Cape Smith and then inland across Ungava Peninsula (Taylor 1982). It has a series of northeastward-trending thrust faults, and is composed of deformed or partly metamorphosed sedimentary and volcanic rock of Proterozoic age. The Kaminak Subprovince underlies the coast and adjacent waters between Arviat and Rankin Inlet (Douglas 1972; Donaldson 1986). It is a belt of deformed and metamorphosed volcanic and sedimentary rocks, mostly of Archaean age.

Three geological subdivisions of the Churchill Province underlie southeastern Hudson Bay, the Richmond Gulf Embayment, Nastapoca Homocline, and Belcher Fold Belt. The Richmond Gulf Embayment (term introduced by Sanford et al. 1979 for Proterozoic strata within the Richmond Gulf area) extends inland to underlie Richmond Gulf and form most of its coastline. It consists mainly of fluvial redbeds and associated terrestrial basalt that have been gently folded, faulted, and eroded. The Nastapoca Homocline is a broad pericratonic belt of younger deformed and partly metamorphosed sedimentary and volcanic rock that follows the arcing coastline of Hudson Bay. It dips gently westward and forms the Hudson Bay coastline west of Richmond Gulf and the coastal islands from Cape Dufferin south to Long Island. It also underlies coastal waters of southeastern Hudson Bay offshore to the Belcher Fold Belt, which underlies the offshore water and forms the offshore island groups of southeastern Hudson Bay. This latter pericratonic belt is composed of deformed and unmetamorphosed to slightly metamorphosed sedimentary and volcanic rock. Unmetamorphosed Proterozoic strata, folded into doubly plunging folds, are remarkably well exposed in the Belcher Islands (Donaldson 1986).

Crystalline rock of the Churchill Province is overlain by thick sequences of younger sedimentary rocks of the Hudson Platform on Southampton Island, offshore beneath most of Hudson Bay and western James Bay, and along the southern coast from the Knife Delta in Manitoba east to the Nottaway River (Douglas 1973).

The Hudson Platform consists of the erosional remnants of the Moose River and Hudson Bay cratonic basins which are separated by the northeastward-trending Cape Henrietta Maria Arch (Norris 1986, 1993). It consists of a succession of flat-lying or little deformed carbonate-dominated sedimentary rocks of Ordovician (478-438 MYBP), Silurian (438-408 MYBP) and Devonian (408-360 MYBP) age, mainly limestone and dolostone (Figure 3-2) (Sanford et al. 1968; Norris and Sanford 1969; Sanford and Norris 1973, 1975; Heywood and Sanford 1976; Norris 1986, 1993). These layers have a total thickness of at least 1575 m in the central offshore part of the Hudson Bay Basin and 750 m in the centre of the basin, which lies southwest of James Bay (Norris

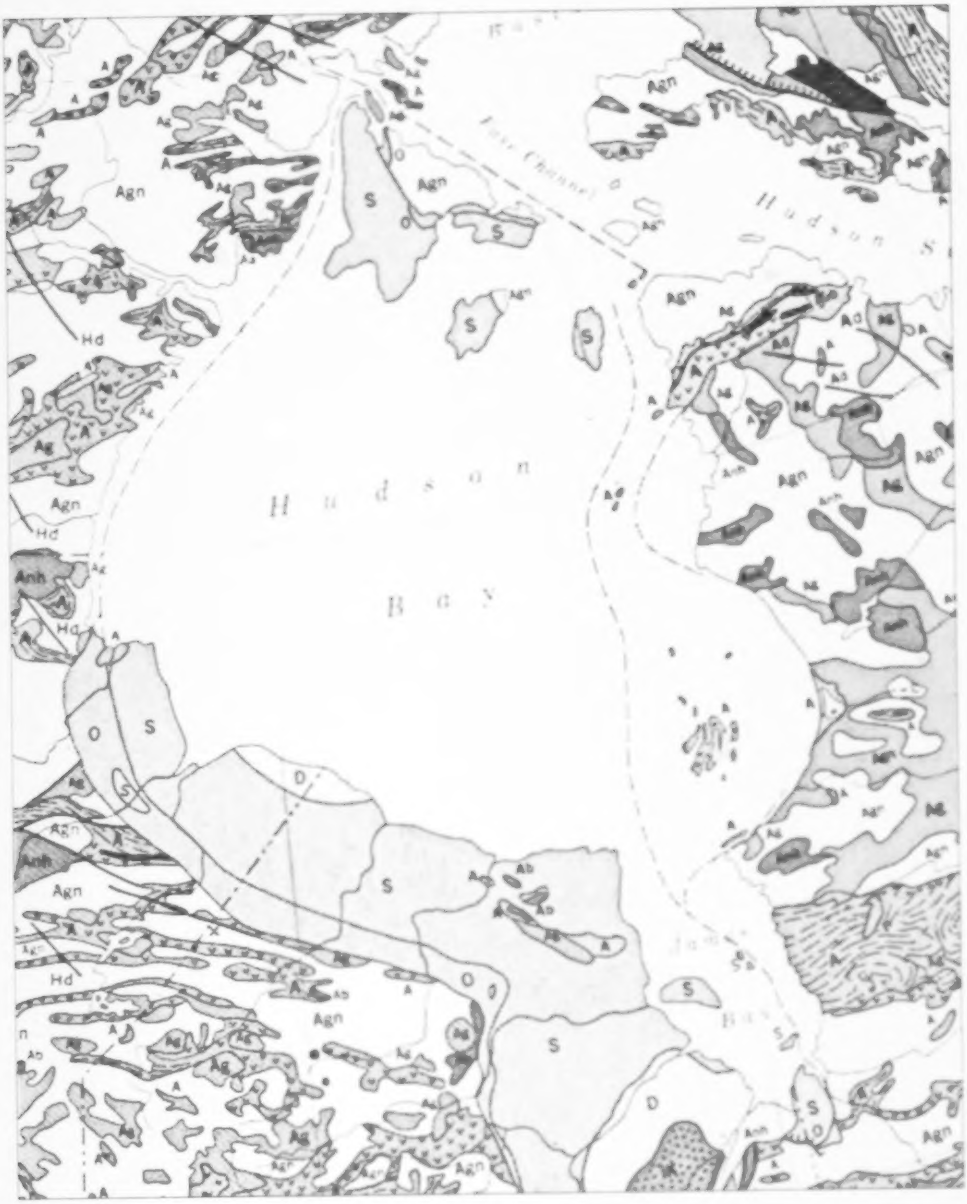
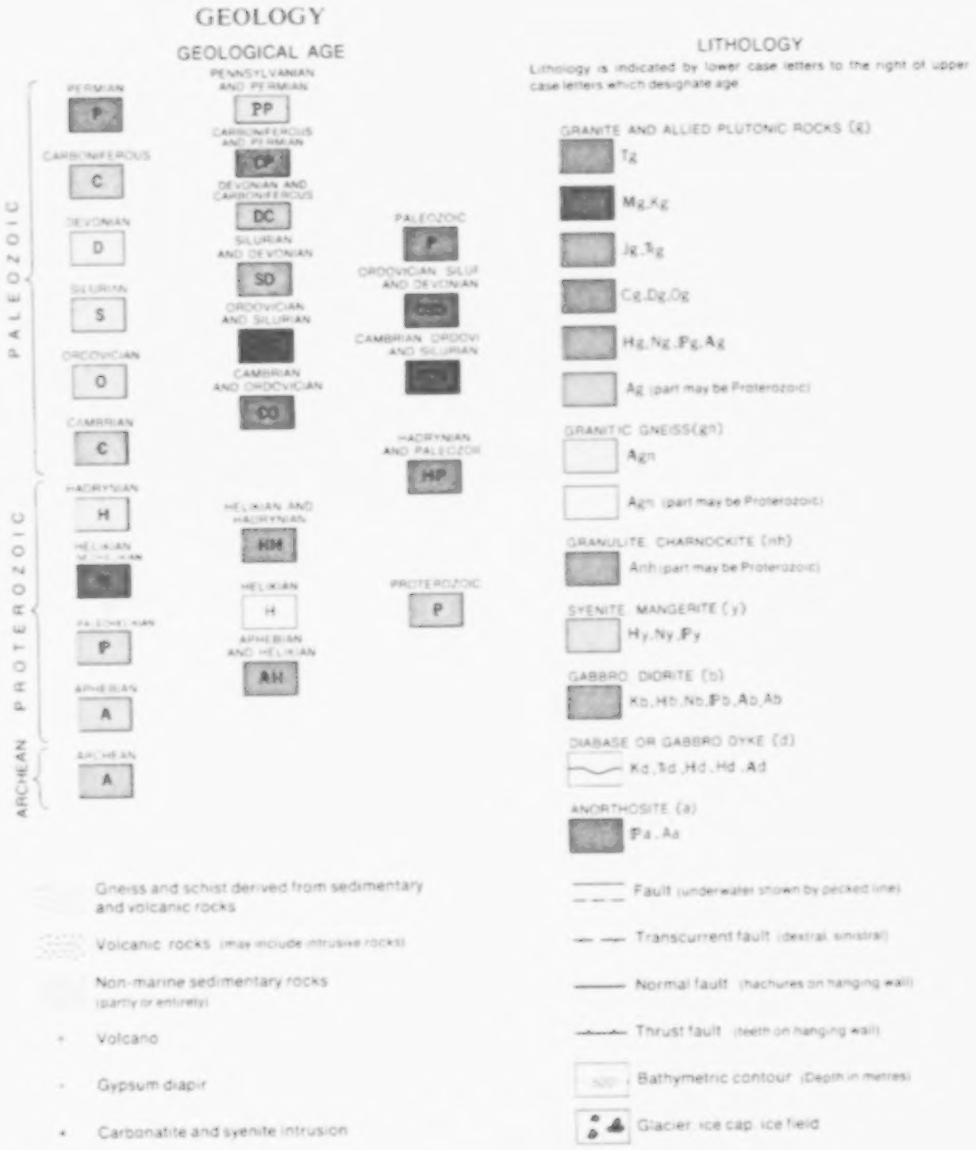


Figure 3-2. **Geology (from Douglas 1969). Key on opposite page.**

1986), and are the result of periodic sediment deposition from shallow seas and terrestrial systems (Shilts 1982; Larsson and Stearn 1986). Coastal boundaries between The Shield and Hudson Platform occur at Churchill and in the vicinity of the Nottaway River (Hardy 1982). There is an outcrop of older Proterozoic sedimentary bedrock at Churchill, consisting mainly of subgreywacke and conglomerates (Sanford et al. 1968; Bostock 1969; Dredge and Nixon 1986). There is no positive evidence for the presence of more recent Mesozoic (230-65 MYBP) strata below the waters of Hudson Bay or James Bay (Telford and Long 1986), but rocks of Mesozoic age have been found in the Moose River Basin southwest of James Bay (Norris 1993). Cretaceous strata, possibly erosional remnants, up to 150 m thick have also been identified in the north-central part of the Hudson Bay Basin (Norris 1993).


GEOLOGY
GEOLOGICAL AGE
PALEOZOIC
PROTEROZOIC
ARCHEAN
PERMIAN
P
CARBONIFEROUS
C
DEVONIAN
D
SILURIAN
S
ORDOVICIAN
O
CAMBRIAN
C
HADRYNIAN
H
HELIKIAN NEOHELIKIAN
PALEOHELIKIAN
P
APHEBIAN
A
ARCHEAN
A
PENNSYLVANIAN AND PERMIAN
PP
CARBONIFEROUS AND PERMIAN
CP
DEVONIAN AND CARBONIFEROUS
DC
SILURIAN AND DEVONIAN
SD
ORDOVICIAN AND SILURIAN
CAMBRIAN AND ORDOVICIAN
CO
HELIKIAN AND HADRYNIAN
HH
HELIKIAN
H
APHEBIAN AND HELIKIAN
AH
PALEOZOIC
P
ORDOVICIAN, SILURIAN AND DEVONIAN
CAMBRIAN, ORDOVICIAN AND SILURIAN
HADRYNIAN AND PALEOZOIC
HP
PROTEROZOIC
P
LITHOLOGY
Lithology is indicated by lower case letters to the right of upper case letters which designate age
GRANITE AND ALLIED PLUTONIC ROCKS (g)
Tg
Mg,Kg
Jg,Tg
Cg,Dg,Og
Hg,Ng,Pg,Ag
Ag (part may be Proterozoic)
GRANITIC GNEISS (gn)
Agn
Agn (part may be Proterozoic)
GRANULITE, CHARNOCKITE (nh)
Anh (part may be Proterozoic)
SYENITE, MANGERITE (y)
Hy,Ny,Py
GABBRO, DIORITE (b)
Kb,Hb,Nb,Pb,Ab,Ab
DIABASE OR GABBRO DYKE (d)
Kd,Td,Hd,Hd,Ad
ANORTHOSITE (a)
Pa,Aa
Gneiss and schist derived from sedimentary and volcanic rocks
Volcanic rocks (may include intrusive rocks)
Non-marine sedimentary rocks (partly or entirely)
Volcano
Gypsum diapir
Carbonatite and syenite intrusion
Fault (underwater shown by pecked line)
Transcurrent fault (dextral, sinistral)
Normal fault (hachures on hanging wall)
Thrust fault (teeth on hanging wall)
500
Bathymetric contour (Depth in metres)
Glacier, ice cap, ice field

Outcrops of crystalline and sedimentary bedrock comprise much of the west coast of Hudson Bay north of Arviat, the east coast north of James Bay, and the surface of the islands but they are less common to the south along the east coast of James Bay, and are rare or absent on the larger islands of James Bay and along the Ontario coast (Canada 1974). In these areas, the bedrock is covered by wetlands or buried under a veneer of boulders, gravels, sand, silt, clay, organic soils, or other loose material resulting from glaciation, marine inundation, weathering, or other natural processes (see also Section 4.5) (Canada 1974; Gilbert et al. 1985; Dredge and Cowan 1989; Henderson 1989; Vincent 1989).

An intriguing feature of the southeastern Hudson Bay coast between Long Island and the Hopewell Islands is its remarkably close approximation to a circular arc. One theory proposed to explain this morphology is that a large asteroid may have impacted immediately west of the Belcher Islands (Beals 1968; Webb 1976). This theory is not supported by geological evidence (Wilson 1968; Donaldson 1986). The arc is more likely the result of normal non-catastrophic geological processes, since the folding of strata typically occurs in arcuate belts and basinal subsidence also commonly produces near-circular basin margins. Indeed, uplift is constantly altering the shape of the coastline and its present "clean curve" may be largely coincidental--it was not a clean arc in the past (Dyke and Prest 1986) nor will it be so in future (H. Josenhans, GSC, Victoria, pers. comm.).

Offshore, the lithology of the Precambrian Shield is not well known (Coles and Haines 1982). Characteristic magnetic signatures suggest that subduction, the process whereby a plate of the earth's crust is forced downward into the earth's mantle, has occurred in the south-central part of Hudson Bay. This may represent a zone where the Churchill and Superior structural provinces meet and could alter the tentative border between the geological provinces. Subduction is thought to be the cause of earthquakes that occur in island arc regions (Watt 1981). They can also be associated with isostatic rebound, which is extensive along the Québec coast (H. Josenhans, GSC, Victoria, pers. comm.). There are also magnetic indications of several northeasterly-trending faults in northern Hudson Bay (Coles and Haines 1982).

The centrally located thick sequence of sedimentary rock in the Hudson Bay Basin has attracted some offshore petroleum exploration (EAG 1984; Johnson et al. 1986), and bedrock drilling has been carried out along the coasts of Ontario and Manitoba (Johnson and Nelson 1969; Sanford and Norris 1975; Young et al. 2003). The best source rocks found in the Hudson Bay Basin to date are the petroliferous Ordovician shales that outcrop on Southampton Island (Nelson and Johnson 1966, 1976; Sanford and Norris 1973, 1975; Heywood and Sanford 1976; Nelson 1981; Dewing and Cooper 1991). Nelson (1981) calculated their total oil reserves to approach or exceed 30×10^9 m^3 (190 billion barrels) (see also Section 15.2).

Economically attractive hydrocarbon resources have not been identified in or near southeastern Hudson Bay or James Bay (Martison 1953; Nelson and Johnson 1966; Sanford and Norris 1973, 1975; Johnson et al. 1986; Sanford et al. 1993). There are geological similarities between the Moose River Basin and oil and gas producing areas of southern Ontario, but petroleum reservoirs have not been located. Two unsuccessful drill tests were conducted in 1971. There are deposits of oil shale and coal southwest of Moosonee (Van der Flier-Keller and Fyfe 1987; Sanford et al. 1993), and small coal deposits near Churchill (G. Young, MB Museum, pers. comm.).

Iron deposits and very strong magnetic anomalies have been mapped in coastal areas of the Hudson Platform and offshore in Hudson Bay (Johnson et al. 1986). There is an iron formation covering over 250 km^2 offshore 100 km north-northeast of Churchill (Hood et al. 1969). Large tonnages of iron mineralization of a grade suitable for mining occur in Proterozoic strata in the Belcher and Nastapoca islands, and in the Grande Baleine and La Grande River areas (Eade 1966; Buck and Dubnie 1968; Johnson et al. 1986). Each of these deposits contains reserves in hundreds of millions of tonnes, with 25 to 40 percent iron as magnetite and hematite. A deposit of lead and zinc has also been located at Richmond Gulf, and there is a high-purity gypsum deposit southwest of Moosonee (Sanford et al. 1968). None of these mineral deposits is, however, sufficiently economically attractive to develop for production.

Precambrian terrains bordering the Hudson Platform may hold important mineral deposits (Johnson et al. 1986). The Cape Smith Fold Belt contains asbestos, copper, and nickel ore--some of which has been mined or is under development in Québec (Taylor 1982). There are several small but rich copper-nickel deposits near Rankin Inlet (Weeks 1931), one of which was exploited by the North Rankin Nickel Mine (Whitmore and Liberty 1968). The coastally situated mine produced over half a million tonnes of ore from 1957 to 1962 with a grade of 0.8% copper and 3.3% nickel (Heywood 1973). Recent mineral exploration and development activities bordering the marine ecosystem are discussed in Section 15.3.

3.2 GLACIATION

Glaciations have had a profound effect on the evolution of the coasts and sea floor of the Hudson Bay marine ecosystem. Continental ice sheets, each with their associated erosional, depositional, glacio-hydrological, loading, and climatic cycles, have covered it at least twice (Skinner 1973; Denton and Hughes 1981; Dredge and Neilson 1985; Dredge and Cowan 1989) and perhaps as many as seven times (Shilts 1982, 1984, 1986; Andrews et al. 1983) during the past million years. They have affected the coastal relief and development, surface and sea floor materials, bathymetry, biological species composition, human activity, and many other regional features.

Because each glacial event obscured evidence of the previous one, the glacial history is a matter of considerable debate. The stratigraphic sequences of glacial, fluvial, terrestrial, and marine deposits in the sediment of the Hudson-James Bay Lowlands suggest that glaciers, at least in central Hudson Bay, retreated enough to permit marine incursions to the lowlands on six or seven separate occasions (Shilts 1982, 1984, 1986; W.W. Shilts, pers. comm.). Many of the modern characteristics of the Hudson Bay-James Bay basin are derived from the processes that accompanied the last ice retreat (Shilts 1986; Josenhans and Zevenhuizen 1990).

The last glaciation of the region was effected by the Laurentide Ice Sheet, a continental ice sheet consisting of glaciers that likely emanated from centres around, rather than in, Hudson Bay (Shilts 1982, 1986). These centres of outflow shifted position and interacted with each other in complex ways in space and time. Their exact configurations are a matter of debate (Andrews and Miller 1979; Dyke et al. 1982; Shilts 1982, 1986; Peltier and Andrews 1983; Dredge and Cowan 1989; Henderson 1989; Vincent 1989; Josenhans and Zevenhuizen 1990; Lajeunesse and Allard 2003).

Distinctive rocks from the Belcher Islands, Dubawnt redbeds, Ottawa Islands and other areas, some of them now beneath marine waters, were carried long distances by the glaciers (Laverdière et al. 1981; Shilts 1982, 1986; Adshead 1983a-c; Henderson 1989). The dispersal of these erratics and the orientation of ice eroded or moulded landforms, such as surface striations on the granite bedrock and drumlinoid ridges, evidence some of the glacier's movements (Gray and Lauriol 1985; Lauriol and Gray 1987; Dredge and Cowan 1989; Vincent 1989; Josenhans and Zevenhuizen 1990). For example, ice emanating from a centre in Nouveau Québec-Labrador carried rock from the Belcher Islands into southwestern Ontario, throughout much of the area north of Lake Superior, and even as far west as Alberta (Dredge and Cowan 1989). Ice emanating from central Kivalliq carried rocks from the Dubawnt redbeds southwest of Baker Lake all the way to Coats Island, dispersing them in a broad curving train across eastern Kivalliq and over the seafloor of Hudson Bay (Shilts 1982, 1986). Softer rocks often bear the marks of both glacial ice and later drift ice (Laverdière et al. 1981). The irregular, often intersecting, abrasions left by the latter can obscure the regular parallel striations of the glacial ice. There are good examples of abrasion marks caused by drift ice on the basaltic shores of Manitounuk Sound and Long Island.

During deglaciation a remnant Laurentide ice mass occupied Hudson Bay and served as an ice dam for glacial lakes Agassiz and Ojibway (Dyke and Prest 1987; Shoemaker 1992; Barber et al. 1999). These large proglacial lakes were situated at the southern and western margins of the retreating ice sheet and drained south into the St. Lawrence River estuary (Vincent and Hardy 1979). They were refugia for many of the freshwater fish and invertebrates that now inhabit fresh waterbodies near James Bay and southeastern Hudson Bay (McPhail and Lindsey 1970; Crossman and McAllister 1986). About 8,470 years ago (8,160-8740 yBP) there was a rapid collapse of ice in Hudson Bay that allowed >10^{14} m ^{3} of freshwater from lakes Agassiz and Barlow-Ojibway to drain swiftly northward through Hudson Strait to the Labrador Sea (Barber et al. 1999). This large pulse of freshwater reduced the sea surface salinity and altered thermohaline ocean circulation, thereby initiating the most abrupt and widespread cold event to have occurred since glaciation. This event, which occurred about 8,200 years ago, provides perspective both on the sensitivity of ocean circulation to freshwater inputs and on the climatic oscillations of the present interglacial period.

The catastrophic drainage of lakes Agassiz and Barlow-Ojibway was accompanied by the incursion of marine water from Hudson Strait into Hudson Bay. The sea split the glaciers as they melted back toward putative dispersal centres in central Kivalliq, Foxe Basin, and Nouveau Québec-Labrador (Peltier and Andrews 1983;

Shilts 1986; Henderson 1989; Stravers et al. 1992), and penetrated south to James Bay Lowlands about 7800 years ago (Skinner 1973; Hardy 1982). The transition from fresh water, proglacial lake to marine conditions was likely very rapid, with the deglaciation of present day Hudson Bay-James Bay occurring in about 400 years (Dyke and Prest 1987; Josenhans and Zevenhuizen 1990). The many distinctive and well-preserved glacial landforms on the floor of Hudson Bay provide evidence of this rapid transition.

Arctic marine conditions developed in southern Hudson Bay immediately following this marine incursion (Bilodeau et al. 1990). They were characterized by dense seasonal sea-ice and cold Arctic surface water, saline bottom waters ($\geq$33 ‰; ‰=psu) with low dissolved oxygen, and the proliferation of Arctic microflora and microfauna. These conditions were short-lived and by about 6500 yBP full Subarctic conditions persisted. The surface waters were warmer than today, which led to the development of rich dinoflagellate populations, and significant freshwater inputs and intensified mixing of the water column decreased salinity and increased oxygenation of the bottom waters, which led to increased benthic production. These conditions must have been responsible for the considerable number of "relict" Atlantic species in southern Hudson Bay and James Bay. They persisted until about 4000 yBP, since which time there has been a slight cooling of the surface waters and an increase in bottom-water salinity.

Glaciers disappeared completely from the Hudson-James Bay region within about 2000 years after the initial marine incursion (Shilts 1986). Their rate of retreat averaged 300 m y^{-1}, ranging from 167 to 360 m y^{-1} in the La Grande Rivière area (Vincent 1977), and the sea followed the retreating ice front well inland. The retreating glaciers left behind a variety of features, principally interlobate moraines, radial moraines, eskers, and end moraines. One of these, the Hurricana Interlobate Moraine, which developed between major ice domains, extends from central James Bay 1000 km south (Dredge and Cowan 1989; Vincent 1989). This glaciofluvial deposit forms a complex series of ridges up to 10 km wide and 100 m high. Glacial Lake Minto also formed between the Hudson Bay-Ungava Bay drainage divide and the retreating ice front (Lauriol and Gray 1983, 1987). It occupied the area of present day Lac Minto and Rivière aux Feuilles and drained westward into Hudson Bay. When ice that blocked the valley of Rivière aux Feuilles broke up, about 5000 to 5500 yBP, there was a rapid drawdown and the main drainage was re-routed to Ungava Bay.

In Kivalliq, there were two major interruptions to the retreat--possibly the result of climatic deterioration. Zones with a higher density of eskers mark these interruptions, one of which is apparent in the Maguse River area (Figure 3-3). This area is unusual in that it has well developed esker systems that extend into the sea, a wide coastal plain, and very wide tidal flats (Aylsworth and Shilts 1989; W.W. Shilts, pers. comm.). Ice stranding is common along this shallow coast and affects the pattern of sediment deposition. Because the retreating ice was not very active, at least in Kivalliq, a well-developed, integrated drainage net of eskers was left behind on land from the mouth of Hudson Bay to the vicinity of the Keewatin Ice Divide in central Kivalliq. The most extensive marine sediment accumulations were left in areas adjacent to the major esker systems.

Flexibility of the earth's crust allowed the great weight of the Laurentide Ice Sheet to depress the land to elevations 100 to 300 m below the present level (Andrews 1974). This permitted marine waters to flood large areas adjacent to present day Hudson Bay and James Bay as the glaciers retreated inland, despite a sea level that was 100 m lower than today. Lee (1960) termed this earlier, larger configuration of Hudson Bay the Tyrrell Sea.

When the Laurentide Ice Sheet melted the earth's crust began to rebound. This **postglacial uplift** or **isostatic rebound** slowly elevated the land surface, gradually reducing the area of the Tyrrell Sea to its present form as Hudson Bay and James Bay. Prominent strand lines, some of them situated well inland, mark the limit of postglacial marine inundation (Shilts 1986; Dredge and Cowan 1989; Vincent 1989). They vary considerably in age and elevation as a result of this rebound, some of which occurred as the glaciers melted while the land was still covered by ice or water (**restrained rebound**). Scattered fluvioglacial deposits, which were laid down during the retreat of the ice sheet and not entirely buried under sediment deposited by the Tyrrell Sea, can be seen emerging in some coastal areas.

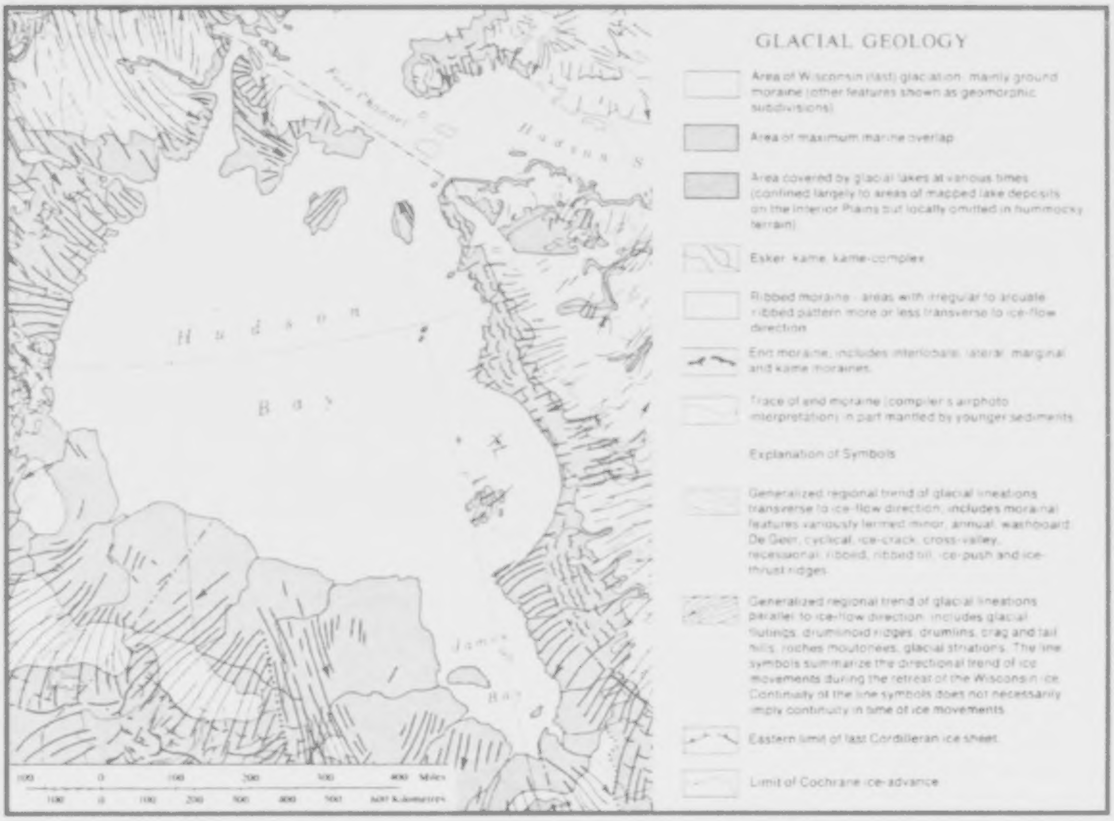

GLACIAL GEOLOGY
Area of Wisconsin (last) glaciation: mainly ground moraine (other features shown as geomorphic subdivisions)
Area of maximum marine overlap
Area covered by glacial lakes at various times (confined largely to areas of mapped lake deposits on the Interior Plains but locally omitted in hummocky terrain)
Esker, kame, kame-complex
Ribbed moraine - areas with irregular to arcuate ribbed pattern more or less transverse to ice-flow direction
End moraine, includes interlobate, lateral, marginal and kame moraines
Trace of end moraine (compiler's airphoto interpretation) in part mantled by younger sediments
Explanation of Symbols
Generalized regional trend of glacial lineations transverse to ice-flow direction, includes morainal features variously termed minor, annual, washboard, De Geer, cyclical, ice-crack, cross-valley, recessional, ribbed, ribbed till, ice-push and ice-thrust ridges
Generalized regional trend of glacial lineations parallel to ice-flow direction, includes glacial flutings, drumlinoid ridges, drumlins, crag and tail hills, roches moutonees, glacial striations. The line symbols summarize the directional trend of ice movements during the retreat of the Wisconsin ice. Continuity of the line symbols does not necessarily imply continuity in time of ice movements
Eastern limit of last Cordilleran ice sheet
Limit of Cochrane ice-advance
Hudson Bay
James Bay
Hudson Strait
Foxe Channel
Miles
Kilometres

Figure 3-3. **Glacial and nearshore features of the Hudson Bay and James Bay coasts (from National Atlas of Canada 4th ed. 1974a).**

This emergence means that the low-lying coastal sections, which occur almost uninterrupted from Arviat in Nunavut to the Conn River in Québec and on the larger islands of James Bay, are dynamic and that the future shape of Hudson Bay and James Bay will be very different from that of today (Barr 1979). In shallow areas of Rupert Bay, for example, post-glacial emergence is causing shoreline progradation at a mean rate of 15 m each year (d'Anglejan 1980). This habitat flux has important ramifications for migratory waterfowl.

The rate of emergence was fast immediately following deglaciation and is an order of magnitude slower today, ranging from 0.7 to 1.3 m per century (Andrews 1970 in Barr 1979; Hunter 1970; Webber et al. 1970; Hillaire-Marcel and Fairbridge 1978; Vincent 1989). Parallel lines of raised marine beaches, complete with sand and ancient shells, provide clear visual evidence of the postglacial rebound in many coastal areas (Brown 1977; Pala and Weischet 1982; Dredge and Cowan 1989; Vincent 1989). Some of the best ridges occur at the northeastern tip of Cape Henrietta Maria, where Hudson Bay and James Bay meet (Martini 1986b), and in Richmond Gulf, where dateable flights of raised beaches rise 270 m asl (H. Josenhans, GSC, Victoria, pers. comm.; Hillaire-Marcel 1976; Josza and Parker 1981; Vincent 1989).

The rate of rebound varies around the region's coasts. In the Richmond Gulf area the rate of uplift has slowed from 9.6-10.0 m per century immediately following deglaciation (Allard and Seguin 1985) to 1.1 m per century (Hillaire-Marcel 1976). The estimated rate of uplift at Cape Henrietta Maria is also high, 1.2 m per century during the last 1000 y (Webber et al. 1970), suggesting that another centre of maximum postglacial uplift is located in that area. At Churchill, Manitoba the rate of uplift is estimated at 0.8-0.9 m per century (Tushingham 1992). Extrapolations of postglacial emergence curves from the area suggest a maximum marine inundation of

>300 m, similar to that for the Grande rivière de la Baleine area. Substantial rebound may have occurred southwest of James Bay before marine incursion, since it rebounded slower immediately following deglaciation and has lower marine limits (e.g., 180 m above sea level) (Dredge and Cowan 1989). The present rate of rebound at Rupert Bay is estimated at 1 m per century (d'Anglejan 1980).

The inland limits of marine inundation vary in elevation around the coast. In the west, they are lowest in the Wager Bay area (100-125 m asl) and elsewhere are typically in the range of 150-180 m asl (Dredge and Cowan 1989; Dyke and Dredge 1989). Along the east coast, the marine limits increase from 198 m above sea level (asl) at the south end of James Bay to 315 m asl east of Manitounuk Sound and then decrease to 140 m asl east of Inukjuak (Hillaire-Marcel 1976; Vincent 1989). A unique negative free-air gravity anomaly that is centred on Hudson Bay shows a remarkable correlation with the location of the Laurentide Ice Sheet and may be the result of incomplete post-glacial rebound (Simons and Hager 1997).

3.3 COASTAL FEATURES

The coastal environment of Hudson Bay and James Bay is dynamic and well studied relative to other Arctic marine regions. Subject to rapid postglacial uplift, it is constantly changing and is a good area for the study of emergent processes such as soil formation and vegetational succession. It offers superb examples of emergent features and a variety of coastal types. The coast is also cold for its latitude and provides a southerly and relatively accessible area for the study of subarctic coastal processes and vegetational transition zones. The wide tidal flats and salt marshes provide vital seasonal habitats for migratory waterfowl and shorebirds, and may be vulnerable to the effects of water developments (see Chapter 15) and climate change (see Chapter 17).

The coastal morphology generally reflects the underlying geological structure, the type of glacial erosion it has undergone, and the local deposition of glacial landforms (Dunbar and Greenway 1956; Martini 1986b). There are three basic coastal types in the ecosystem: 1) low-lying, 2) cliff and headland, and 3) complex (Figure 3-4).

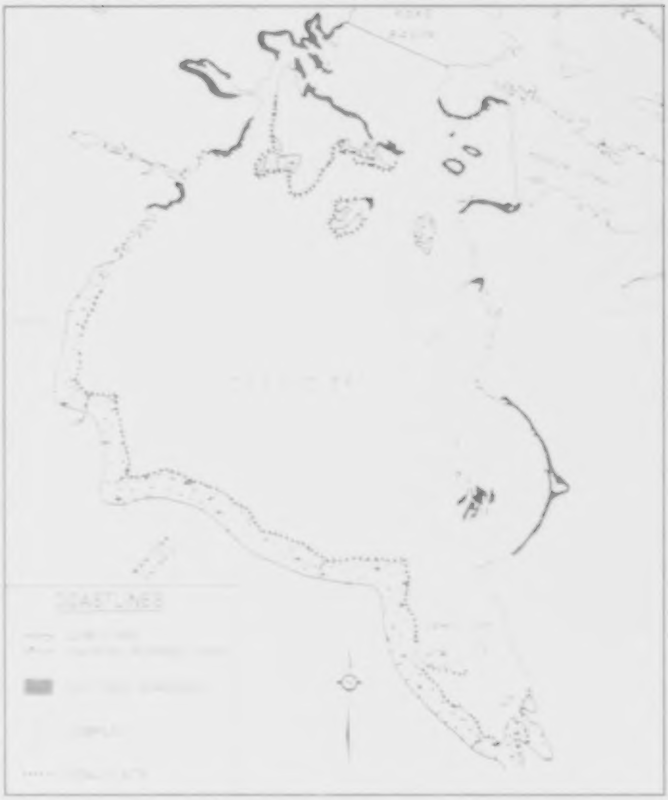


Figure 3-4. **Coastal types bordering Hudson Bay and James Bay (adapted from EAG 1984).**

3.3.1 Low-lying Coasts

The low-lying coastal sections occur more or less continuously along the mainland coast of Hudson Bay and James Bay from Arviat in Nunavut southward and eastward to the Conn River in Québec; along the southwestern coasts of Southampton, Coats, and Mansel islands in northern Hudson Bay; and on the larger islands of James Bay, including Charleton, Akimiski, North Twin and South Twin (Figure 3-5). These recently emerged coasts are characterized by extensive tidal mud flats that give way to low-lying, marshy coastal plains (Coombs 1954; EAG 1980, 1984; Martini 1981a+b, 1982, 1986b; Pala and Weischet 1982; Dredge and Nixon 1986; see also LUIS maps; Figure 3-6). There are few bedrock outcrops and most of the surface material is unconsolidated. Most of the low-lying coastline is underlain by Paleozoic rock and nearly devoid of small islands;

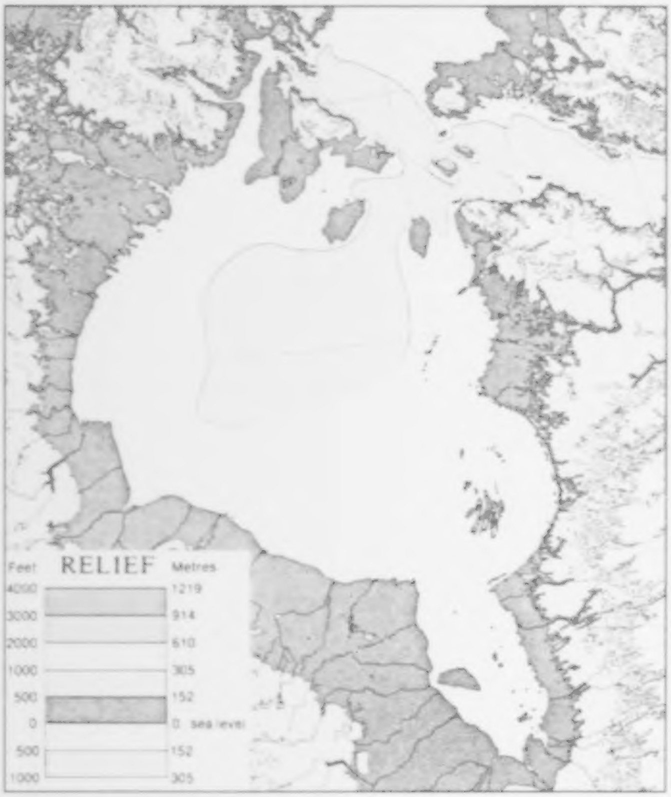


Figure 3-5. **Relief (from National Atlas of Canada 4th ed. 1974b).**

there are a few islands along the low-lying section of the Qubec coast, which is underlain by Precambrian rock. Nearshore waters are generally shallow. The seaward slope is very gentle and in some areas the tidal mud flats extend several kilometres offshore, making access to and from the water difficult and coastal travel in small craft dangerous when winds rise.

With isostatic rebound still occurring, emergence of the mud flats in shallow areas of Rupert Bay is creating new land at a mean rate of 15 m each year (d'Anglejan 1980), while in some other areas little or no emergence has been observed (Martini 1982; Tornocai 1982). Well-developed raised marine beaches and abandoned shores resulting from post-glacial rebound are characteristic features of these coasts (Martini 1982, 1986b; Dredge and Nixon 1986).

The surficial sediments of James Bay's tidal flats show an overall landward-fining (Martini 1986b). They have well defined zonations associated with types of sediments, sedimentary structures, and organisms and show the effects of both ice scour and ice rafting. The surface may be ornamented by ripple marks, occasionally showing herring-bone cross-laminations where the flats are locally influenced by ebb and flood tidal flows. The tidal flats generally support a restricted infauna, dominated by *Macoma balthica* and *Hydrobia minuta*, and are skirted by wide coastal marshes (Martini 1984). Permafrost and the poor drainage along the newly emerged coasts give rise to wetlands, and gleysolic and organic soils develop with a shallow active layer (Protz 1982a; Tornocai 1982). The permafrost forms a barrier that limits the interaction of wetlands with groundwater and the availability of subsurface water to terrestrial vegetation (Woo and Winter 1993).

Extensive salt marshes are an important and characteristic feature of the low-lying coastlines. These marshes provide vital habitat for many migratory waterfowl and shorebird species (Martini et al. 1980b; Morrison and Gaston 1986). They often have seaward slopes of <2 m per km, and show species zonations that are clearly linked to salinity and elevation, water content, and soil texture (Ringius 1980; Glooschenko and Clarke 1982; Protz 1982a; Riley 1982a; Martini and Glooschenko 1984; Ewing and Kershaw 1986; Earle and Kershaw 1989).

Salt in the coastal marshes may be introduced by different processes and from different sources, particularly by molecular diffusion from underlying post-glacial marine deposits and by tidal inundation (Price and Woo 1988a-c, 1990; Price et al. 1988, 1989). The salinity generally decreases rapidly after uplift (Protz 1982a), and with distance inland--where the salt loss processes have proceeded for a longer time (Price and Woo 1988a+b). However, "inverted marshes" occur locally along the James Bay coast where species typical of fresh water are the first colonizers, and brackish and salt marsh species are found further inland (Martini et al. 1980b). This phenomenon is unusual and may result from the local trapping and evaporation of brackish water supplied by storm surges (Glooschenko and Clark 1982), freshening of the intertidal zone by low-salinity tidewaters (Price et al. 1989), or other processes.

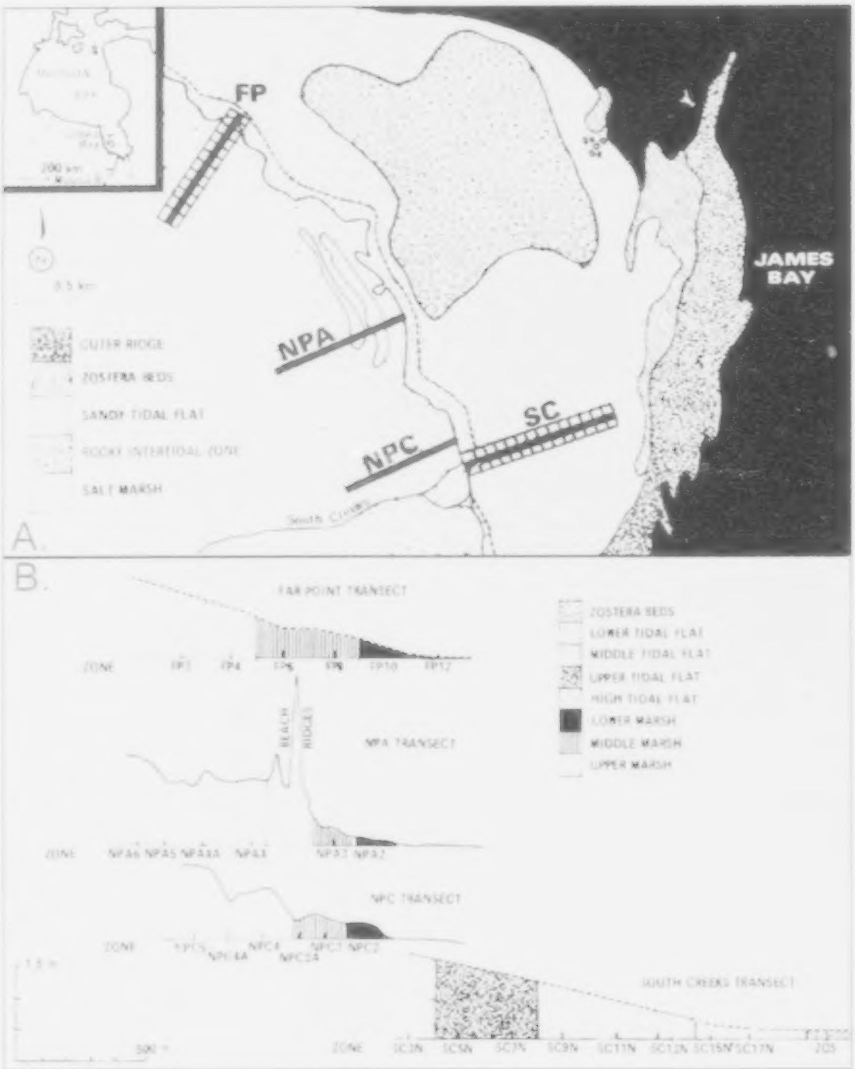


Figure 3-6. **Typical beach transects in western James Bay (A) and their marsh levels, tidal flats and *Zostera* beds (B) (adapted from Clarke et al. 1982).**

The dominant plant species colonizing the intertidal lower marshes are *Puccinellia phryganodes*, *Potamogeton filiformis*, *Eleocharis* spp., and *Hippuris tetraphylla* (Glooschenko 1978; Martini et al. 1980a+b; Ringius 1980; Protz 1982a; Martini and Glooschenko 1984; Ewing and Kershaw 1986; Earle and Kershaw 1989). These salt-tolerant species give way to *Potentilla egedii* and *Carex subspathacea* in the upper marshes that are only occasionally submerged by the tide. Salt marshes in Hudson Bay have a higher occurrence of salt-tolerant species than those in James Bay (Ewing and Kershaw 1986; Price et al. 1988).

These salt marshes are more productive than lake and stream ecosystems and most oceanic and tundra ecosystems, but less so than the temperate grasslands or the boreal forest (Glooschenko 1978). Important factors determining the productivity include length of the growing season as influenced by soil and sediment temperature, soil moisture regime, and salinity.

The time required at Kapiskan River, Ontario, for the vegetation to pass from the emergent stage on the intertidal flats to the thicket stage--a distance of about 1.5 km, ranges from 106 to 142 y (Ringius 1980). The annual rate of advancement of the vegetation is 10 to 15 m y^{-1}. The accumulation of organic soils (**paludification**) begins about 200 y after the landmass emerges from the ocean and increases with distance inland (Protz 1982a). The organic cover, generally peats, increases from a few centimetres in the north to a few metres in the south.

The coastal landscape evolves from one dominated by coastal landforms to one dominated by organic landforms (Martini et al. 1980a). Inland from the tidal flats and salt marshes the soils are better developed and support tundra vegetation in the north, progressing to bogs-organic and boreal forest in the south. The treeline approaches the coast in the north, but seldom reaches it, except near the estuaries of the Churchill and Nelson rivers, until Ekwan Point (Earle and Kershaw 1989).

The southernmost extension of continuous permafrost is found in the Cape Henrietta Maria area (Figure 3-7). Permafrost is widespread immediately south of Cape Henrietta Maria but becomes increasingly scattered moving southward until the southern limit of permafrost is reached near North Point, Ontario, and Rupert Bay, Québec. This extreme southerly extension of permafrost cannot be explained by the region's climate which, based on the number of thawing degree-days, should be too warm to sustain permafrost (Gough and Leung 2002). It can be explained by differences in thermal conductivity of the wetland soil during the freezing and thawing months that are sufficient to effectively reduce the thawing degree-days, or melting depth, and enable permafrost to exist. Ice has a thermal conductivity that is about 4 times greater than water, so warm-season warming does not penetrate as deep as cold-season cooling, reducing the relative effectiveness of the thawing degree days.

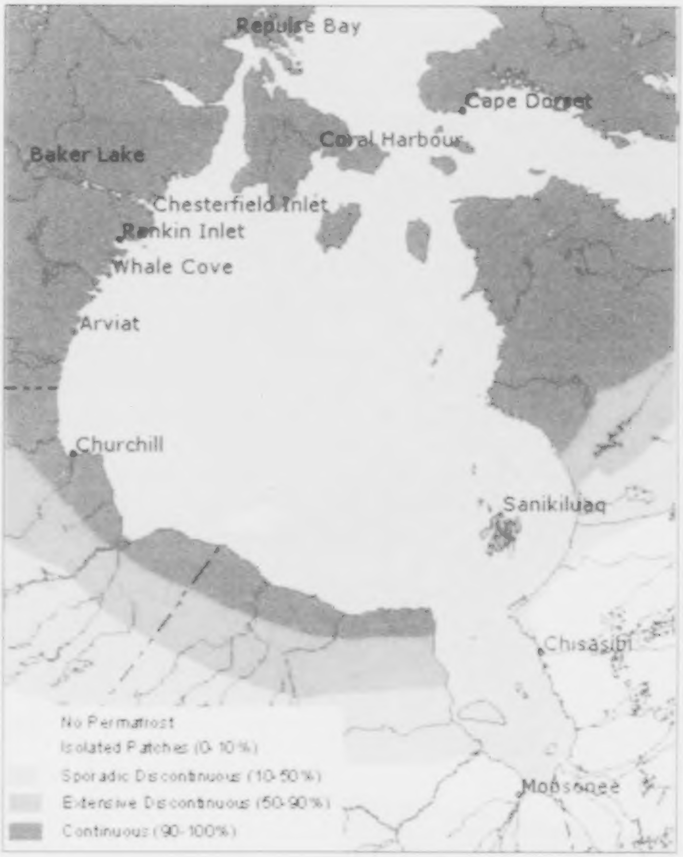


Figure 3-7. **Permafrost (from National Atlas of Canada 6th edn 2003a).**

Most ice-related coastal features are generated by sea ice, rather than permafrost. They include "jig-saw puzzle marshes", boulder push ridges, shallow circular depressions, boulder pavements, a variety of scours generated by moving ice floes, and ice pressure ridges (Dionne 1980b; Martini 1981c, 1986b). Drift ice also scours the tidal marshes and beaches, damaging vegetation, scraping furrows in the surface and depositing detrital material ranging from large boulders to gravel, sand, and peat blocks (Dionne 1974, 1976b, 1978; Martini 1981c).

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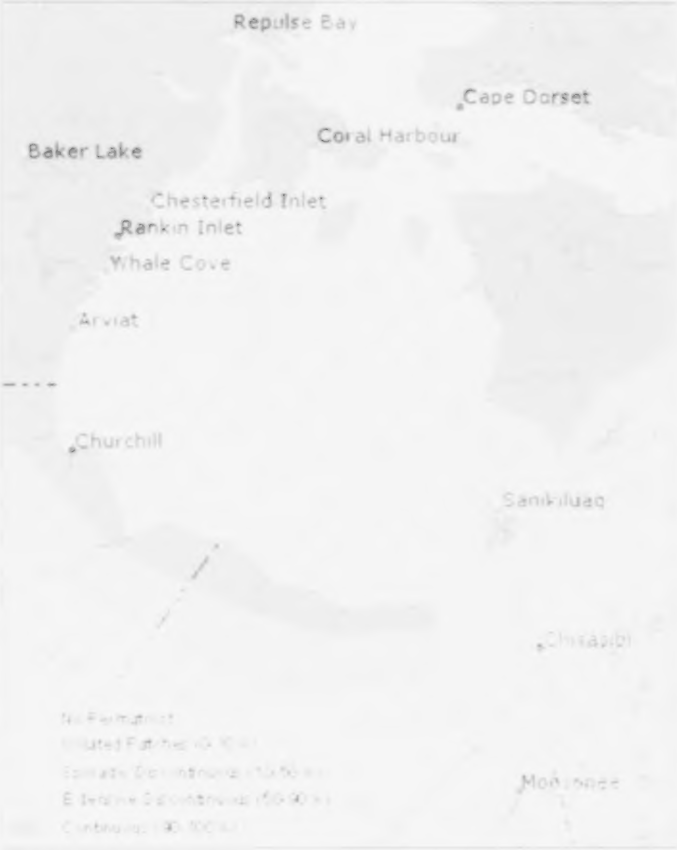

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Major rivers that dissect the low-lying coastal terrains, include: the Seal, Churchill, Nelson and Hayes which drain mainly Precambrian terrains southwest of Hudson Bay; the Severn, Winisk, Ekwan, Attawapiskat, Albany, Moose and Hurricanaw, which drain the Hudson Bay Lowland southwest of James Bay; and the Nottaway, Broadback, and Rupert, which drain the Precambrian terrains southeast of James Bay (Figure 3-8; major = mean annual discharge >2,800 $m^3 \cdot s^{-1}$ at the mouth). Hydroelectric developments have profoundly altered the hydrology--particularly the volume and seasonality of flow, of the Churchill and Nelson rivers in Manitoba (Rosenberg et al. 1995). The Moose River in Ontario is also affected but to a lesser degree, and the Rupert River in Québec may be affected by future hydroelectric development. Flow in the Albany River has been reduced by diversion but its seasonal regime is unchanged. The effects of these developments on the marine ecosystem are discussed in Section 15.1.

3.3.2 Cliff and Headland Coasts

Well-developed cliff coasts and headlands occur along the Québec coast in the Cape Smith area and around the Hudson Bay Arc, from near Kuujjuarapik northward to the Hopewell Islands--including Richmond Gulf; along the mainland coast of Nunavut from Rankin Inlet to Chesterfield Inlet, Daly Bay to south of Wager Bay (65°N 87°08'W), inside Wager Bay from Handkerchief Inlet to Douglas Harbour, and around Repulse Bay; and on the Ottawa and Belcher islands, White Island, and the northeastern coast of Southampton Island (Figure 3-4). Manitounuk Island and the Nastapoca Islands are typical bold cuesta formations with low relief on the westward side and steep slopes on the eastward side (Guimont and Laverdière 1980; Martini 1986b). These areas are associated with broadly developed fault systems and fold blocks, and show a distribution similar to that of submerged canyons and cliffs (EAG 1984; Josenhans et al. 1991). In the middle of the arcing coastline of southeastern Hudson Bay, where elevations reach 500 m, local relief can reach 100 m, exposed bedrock is common, and tidal flats are absent (Figure 3-5) (Gilbert et al. 1985). Underlain by discontinuous permafrost, these coasts are well-drained relative to the low-lying coasts to the south and west (Vincent et al. 1987). Their soils are often rocky, and have a shallow active layer that supports tundra vegetation.

Along the Nunavut coast south of Chesterfield Inlet, and in the Repulse Bay area, local relief in these coastal sections seldom exceeds 30 m. South of Chesterfield Inlet, unconsolidated materials including well-developed networks of eskers are common and there are small tidal flats, marine spits and some rock outcrops (Aylsworth et al. 1986; see also LUIS maps). Gently rolling hills of Precambrian bedrock, often overlain by marine deposits that support tundra vegetation, form the coastline in the Repulse Bay area. Local relief of the cliff and headland coast around Wager Bay, on White Island and along the northeastern coast of Southampton Island is high, >50 m, and the terrain can be very rugged with steep cliffs rising abruptly 300 to 500 m asl (see LUIS maps). Only small rivers and streams dissect the cliff and headland coasts in Nunavut.

Like the low-lying coastlines, these coasts have superb examples of emergent features, particularly the flights of raised marine beaches in the Richmond Gulf area (Vincent 1989; H. Josenhans, GSC, Victoria, pers. comm.) and along the north coast of Southampton Island. They too provide a natural laboratory for the study of rapid coastal regression, where the evolution of deltaic systems and offshore sedimentation patterns can be studied (Lavoie et al. 2002). While underlain by discontinuous permafrost in the south, which becomes continuous to the north, they are dry relative to the lowland coasts, with decreasing organic cover and vegetation moving northward and on the islands, and a shallow active layer (Payette 1976, 1983; Seguin 1976; Seguin and Allard 1984; Martini 1986b; Vincent et al. 1987; see also LUIS maps). Along the east coast, the northern limit of trees (black spruce) is at about 57°10'N, at least 60 km north of the treeline (Payette 1983); trees are absent along the Nunavut coast. These cliff and headland coastal sections support cliff-nesting bird species that are important but uncommon elsewhere in the marine ecosystem.

One of the few large rivers to dissect the cliff and headland coasts is the Grande rivière de la Baleine, which drains Precambrian terrains along southeastern coast of Hudson Bay (Figure 3-8). Part of its flow has been diverted to augment flow to hydroelectric developments on the La Grand river system.

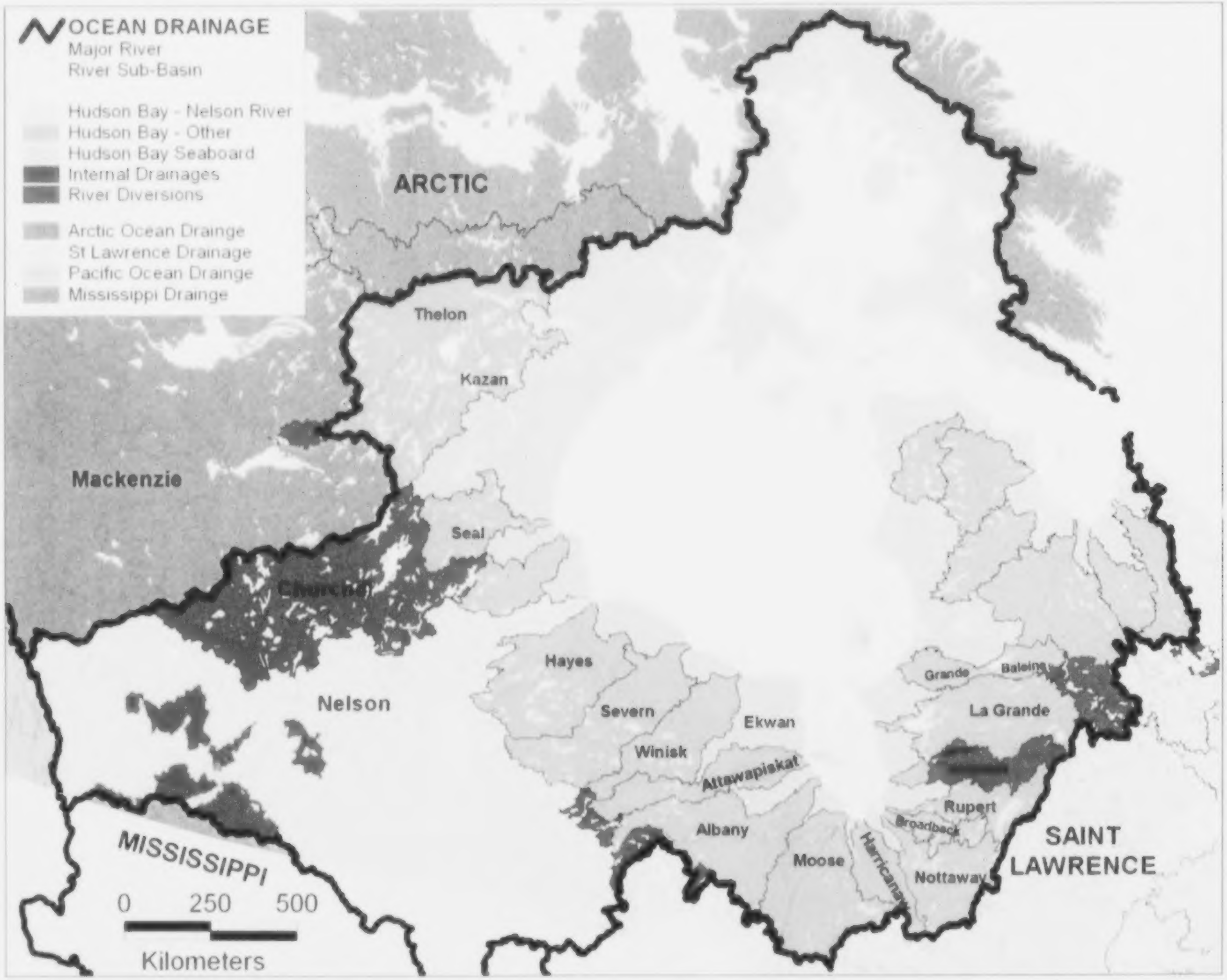

Figure 3-8. River drainages in the Hudson Bay watershed.

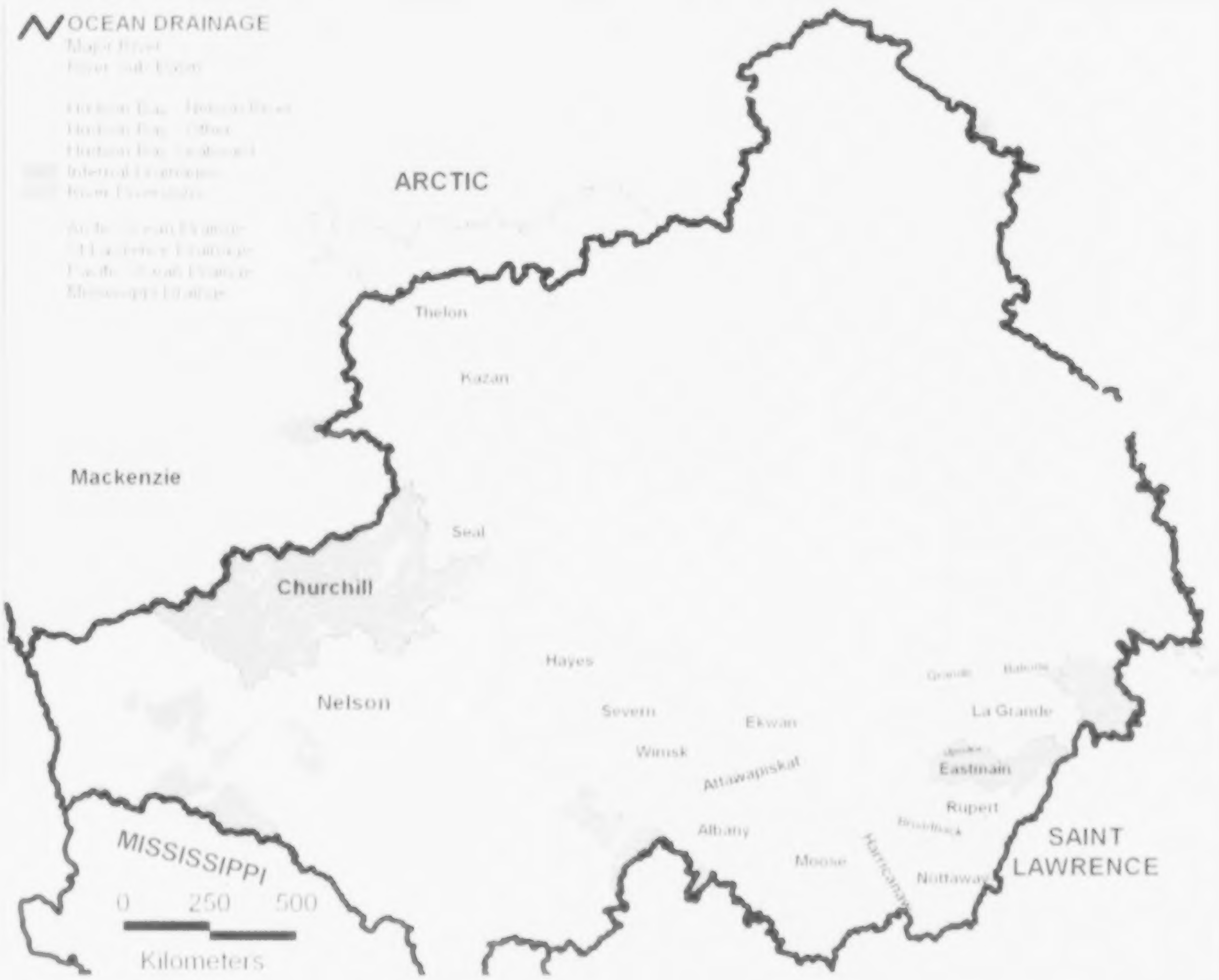

Figure 3-8. River drainages in the Hudson Bay watershed

3.3.3 Complex Coasts

Elsewhere in the region, bedrock folding, volcanism—in some areas, and differential erosion of the exposed rock has created an intricate coastline of small headlands and bays Figure 3-4; EAG 1984; see also LUIS maps).

In Nunavut and along the Québec coast north of Inukjuak, local relief in these complex coastal sections is generally less than 30 m and rocky shores are common. The surface is a mixture of exposed bedrock and unconsolidated materials, underlain by continuous permafrost (Figure 3-7). These coasts are typically well drained, relative to the low-lying coasts. They have barren areas and soils with a shallow active layer that are often rocky and support tundra vegetation. Small tidal flats occur around many of the small bays and islands.

The northeastern coastline of James Bay is the best-known section of complex coastline. It is extremely irregular in shape and is characterized by numerous capes, peninsulas, points, bays, coves, inlets and other indentations of various shapes and sizes (Dionne 1980a). It is also fringed by a myriad of small islands and shoals, and the abundance of small rocky islands, or **skerries**, leads to its further classification as a skerry coastline. Underlain by Precambrian rock, it is a typical low-lying rocky coast (Martini 1986b). The coastal zone in this area is a nearly level plain, or **peneplain**, of Precambrian crystalline rocks sculptured by glacial erosion and having an average height of 30 m asl and little local relief. Nearshore islands, points, and peninsulas are formed mostly of crystalline rocks but some small islands and points are made up of unconsolidated deposits, mainly glacial drumlins and fluvioglacial delta-kames (Dionne 1980a). There are also a few small islands covered by cobble and boulder beaches and a few flying spits. The coastal peneplain is dissected by a number of rivers such as the Eastmain and La Grande, which develop long, shallow, narrow estuaries. It varies in width between 5 and 25 km and is locally covered by thin glacial drift and emerged coastal deposits. Permafrost grades from sporadic near Kuujjuarapik, to isolated in southern James Bay.

The shore and nearshore zones are shallow and gently sloping seaward (Dionne 1980a). No coastal cliffs or significant escarpments develop in James Bay, but wave-cut beaches and bluffs do occur (Dionne 1980a; Martini 1986b). Discontinuous sand, gravel and pebble beaches occur in the upper shore zone, especially in the vicinity of the Eastmain and La Grande rivers (Dionne 1980a). Cobble and boulder beaches are common along rocky shores, wave eroded drumlins and most exposed islands in the nearshore zone where they face the main body of water, especially in the northern part of James Bay between Pointe Kakachischuan and Pointe Louis XIV (Dionne 1980a; Dignard et al. 1991). Tidal flats, some of them fringed inland by wide salt marshes, are found in most large embayments and around most offshore islands. They are similar in many ways to those of the low-lying coasts. A remarkable feature of the complex coastline of northeastern James Bay is the development of vast subtidal meadows of eelgrass (*Zostera marina* L.) (Curtis 1974/5; Dignard et al. 1991; Ettinger et al. 1995).

Miniature injection features including mud volcanoes, dikes forming polygonal patterns, and isolated patches of clay occur in tidal flats of Loon and Dead Duck bays (Dionne 1976a). They are formed by the localized upward ejection of a mixture of fluidized marine clay, silt, and fine sand through a superficial recent mud deposit. Their occurrence in mud flats from a cold region is interesting in that further study may explain how similar formations have occurred in consolidated rock.

The major rivers that dissect the complex coasts are: the Eastmain, Opinaca, and La Grande, which drain Precambrian terrains east of James Bay; the Povungnituk River in northern Québec; and the Thelon and Kazan, which drain large areas of Nunavut via Baker Lake and Chesterfield inlet. Only those rivers that carry considerable amounts of sand develop recognizable delta cones (Martini 1986b). Small delta cones occur in the shore zone at the mouths of the Vieux-Comptoir and Castor rivers, and a larger delta plain is being built at the mouth of the La Grande (Dionne 1980a). Hydroelectric developments have altered the volume and seasonality of flow in the Eastmain, Opinaca and La Grande rivers (Messier et al. 1986). Flow in the La Grande has been augmented by the diversion of flow from the Eastmain and Opinaca rivers, and Grande rivière de la baleine. It may be further increased by the diversion of flow from the Rupert River (Québec 2002).

The complex coastal areas provide the greatest variety of landforms and biological habitats. Particularly important in this regard are the tidal flats, coastal salt marshes, and subtidal eelgrass meadows.

3.4 SEAFLOOR

The sea floor of Hudson Bay is comprised of two saucer-shaped basins, separated by the relatively shallow Midbay Bank (Figure 3-9; Pelletier et al. 1968; Pelletier 1969, 1986; Henderson 1989). The isobaths generally parallel the coast but their concentricity is interrupted by the Midbay Bank in the south, and by a radial system of submarine valleys that are widely spaced around the bay. A deep, trench-like feature called the Winisk Trough extends northward from offshore the Winisk River estuary towards Coats Island. In the north it is about 1.6 km wide and has steep walls that drop from the seafloor to a depth of 370 m (Josenhans and Zevenhuizen 1990). Moving offshore, there is a broad coastal shelf that extends to a depth of about 80 m, a gradual incline or slope where the depth drops from 80 to 160 m, and a smooth continuous seafloor from 160 m to an average depth of 250 m. The shelf extends 20 to 50 km offshore along the Québec coast, about 50 to 70 km from the Manitoba and Kivalliq coasts, and about 100 km from the Ontario shore and northern islands. In southeastern Hudson Bay, depth to the bottom seldom exceeds 120 m except for a line of deeps that parallel the coastline (Josenhans et al. 1991; J. Zevenhuizen, Orca Marine Geological Consultants, Halifax, pers. comm.) (Figure 3-10). James Bay is seldom deeper than 50 m, extremely shallow for such a large marine area.

Bedrock type and pre-glacial erosion have had a profound influence on shaping the bottom topography, and the submarine geology and physiography tend to be extensions of coastal formations and features (Pelletier et al. 1968; Pelletier 1969, 1986; Henderson 1989; Josenhans and Zevenhuizen 1990). Where the seafloor is underlain by Paleozoic sedimentary rock of the Hudson Platform it typically dips gently offshore, and where it is underlain by crystalline Shield rock it tends to be irregular and show greater relief. Pre-glacial erosion has often resulted in the formation of terraces and cuestas in the Paleozoic sedimentary rocks. Indeed, the enclosed bathymetric deeps (>200 m) offshore Grande rivière de la Baleine resemble the adjacent cuesta coastline (Josenhans et al. 1991; J. Zevenhuizen, Orca Marine Geological Consultants, Halifax, pers. comm.). Seabed relief is subdued and generally less than 2° (Josenhans and Zevenhuizen 1990). On the smaller scale, ridges of glacial till up to 15 m high and 300 m wide dominate the relief of the nearshore areas. Ice keel scour marks typically 1-5 m deep, with berms up to 7 m high (average 3 m), form the dominant microrelief of large parts of Hudson Bay. They occur between the depths of 72 and 175 m and were created by glaciers and icebergs in late glacial time. Some areas of the seafloor were not scoured by icebergs and may have been protected by remnants of the Laurentide Ice Sheet (Josenhans et al. 1988). Like the adjacent coasts, the seafloor is rising at a rate of about 1 m per century (E. Thompson, Canadian Hydrographic Service, Burlington, pers. comm.).

Bottom sediment distribution in Hudson Bay is controlled primarily by the last (late Wisconsin) glaciation (Meaghers et al. 1976 in Dionne 1980a; Henderson 1989; Josenhans and Zevenhuizen 1990). The sediment consists primarily of till, fine-grained glaciomarine deposits, and postglacial mud (Figure 3-11). Sediment deposition due to sea-ice rafting is minor. In Hudson Bay, the maximum observed thickness of postglacial sediments is 15 m in the Winisk Trough and till thickness is generally less than 10 m, although moraines up to 55 m thick have been observed in southern Hudson Bay (Josenhans et al. 1988). Glaciomarine sediments overlying the tills are generally less than 5 m thick, although ponded sediments between bedrock highs may be up to 50 m thick (Figure 3-12). Post-glacial sedimentation, which involves reworking of glacially derived sediments by rivers and/or marine currents, is restricted largely to the shallow marine environment (<100 m deep). These sediments are thin (<5 m) and selectively deposited near river estuaries and in localized depressions.

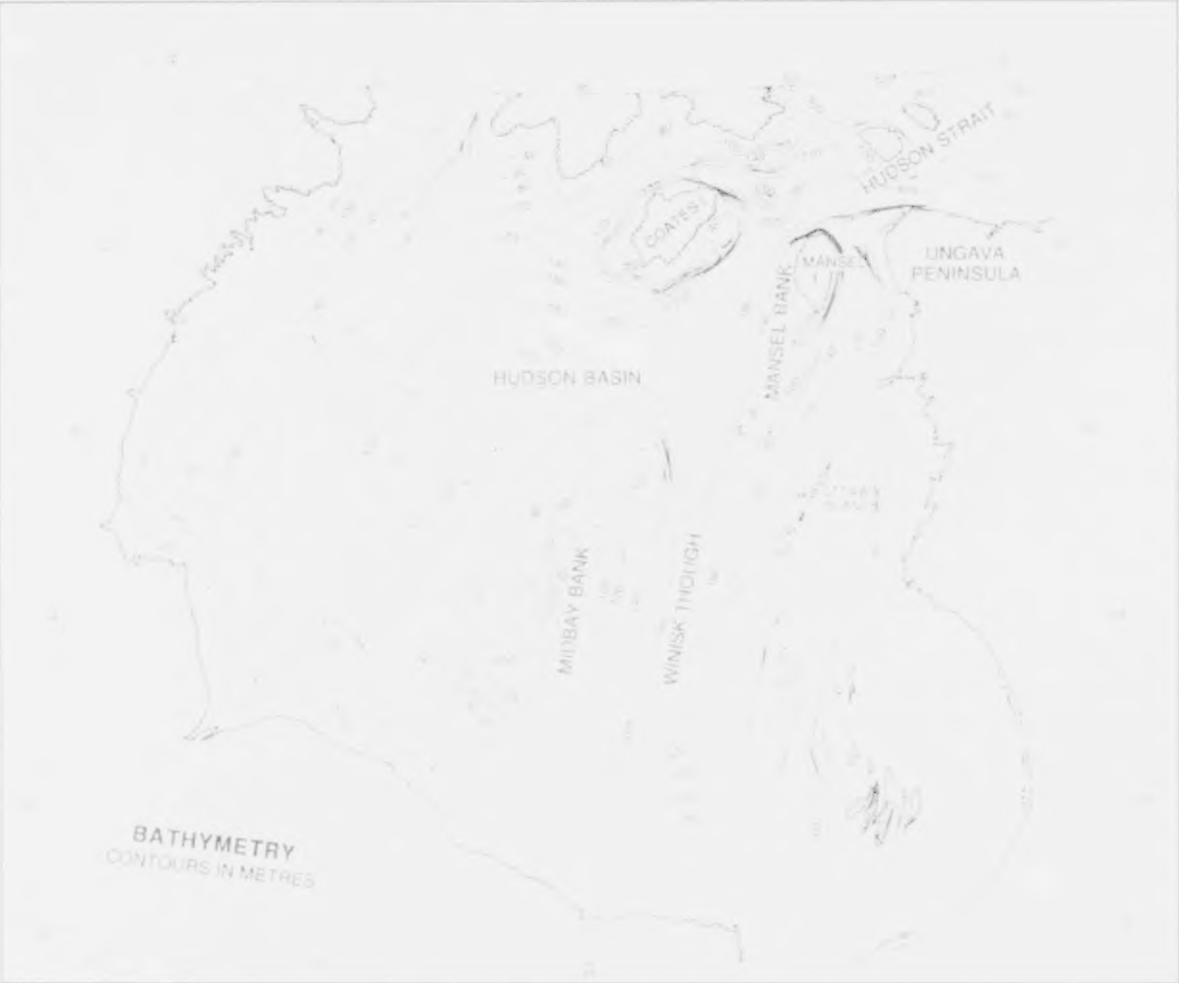

Figure 3-9. Bathymetry (m) of Hudson Bay (adapted from Josenhans et al. 1988, p. 274).

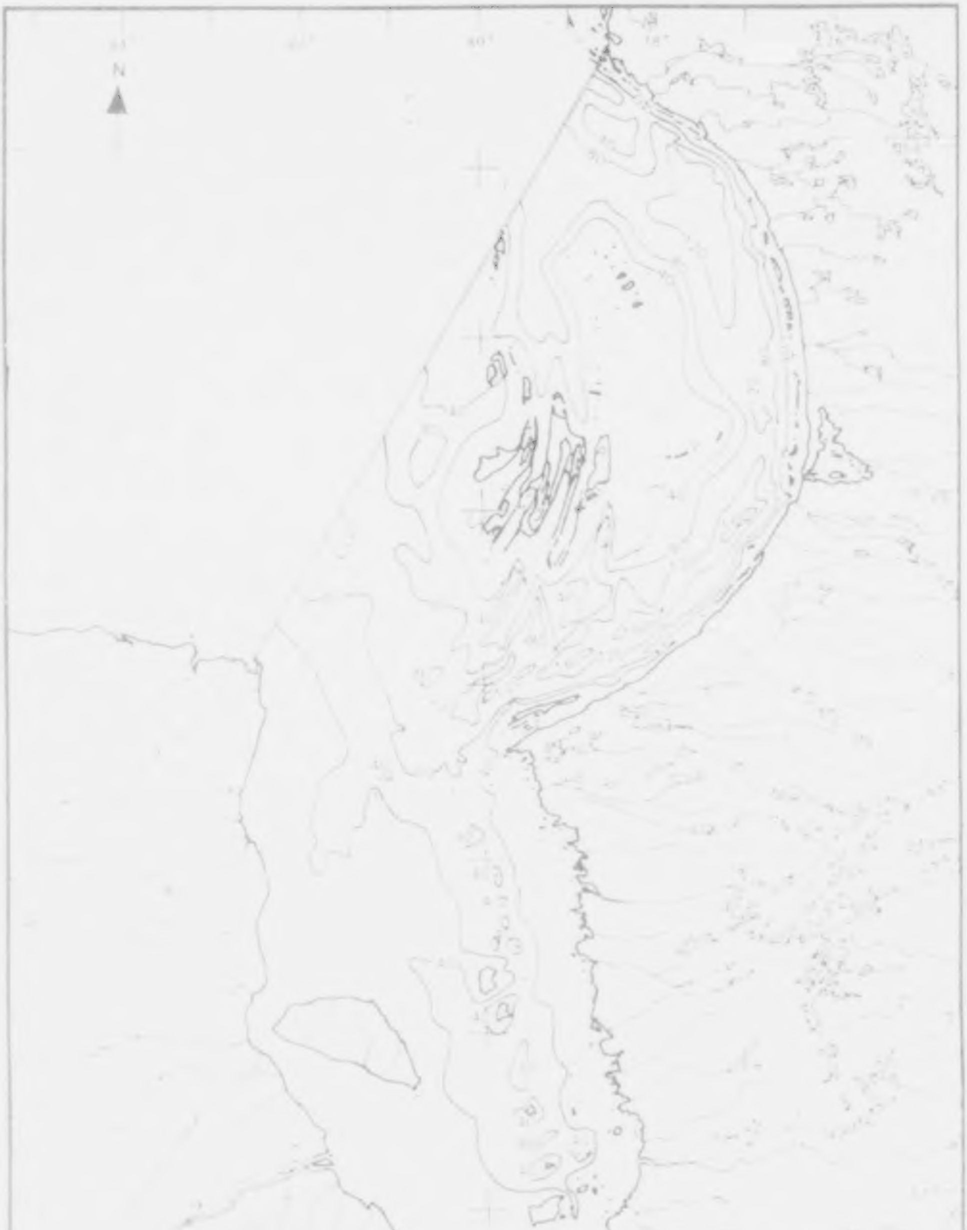

Figure 3-10. Bathymetry of James Bay and southeastern Hudson Bay (from Stewart et al. 1993). The contour interval is 40 m.

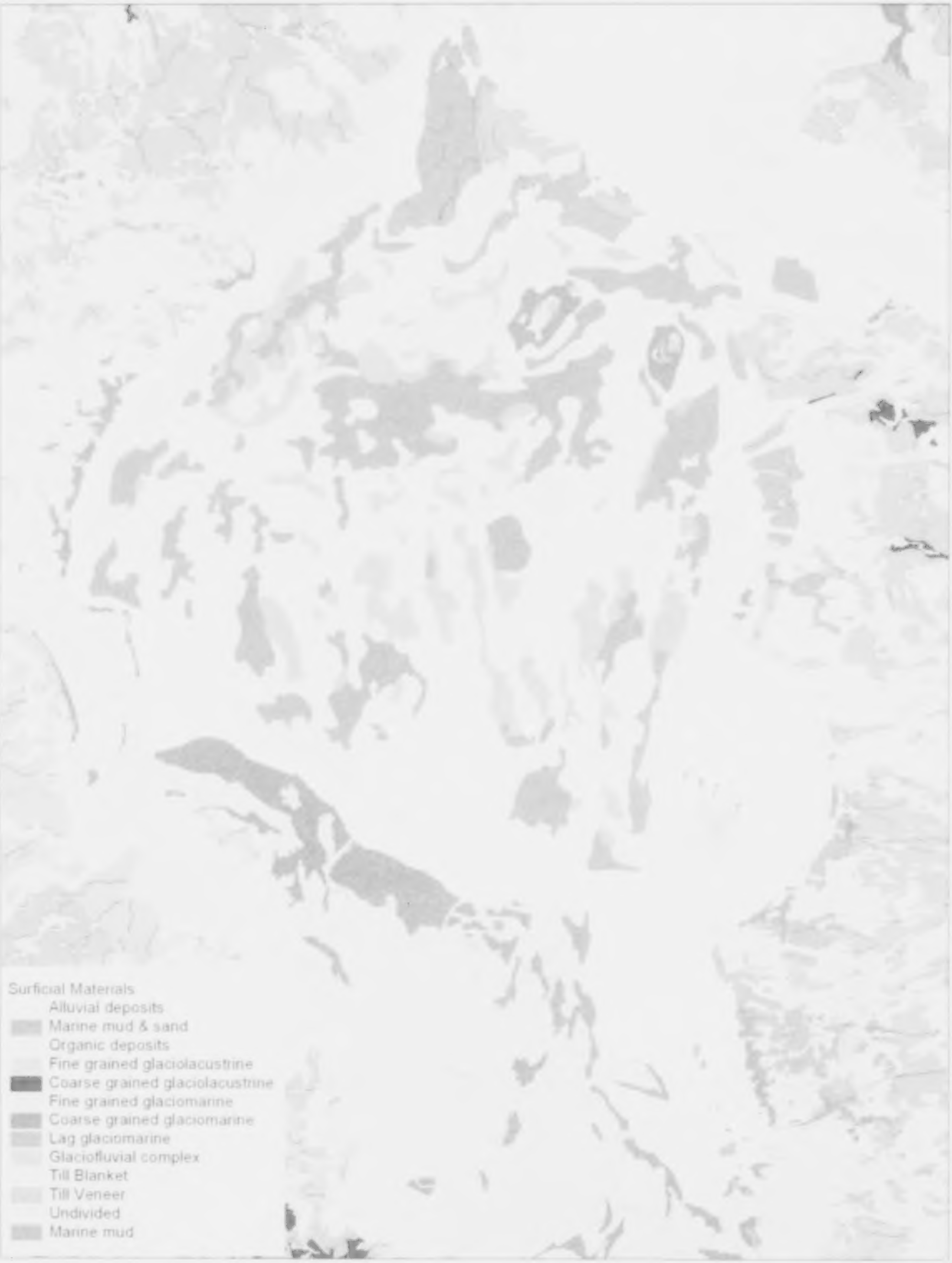

Figure 3-11. Broad categories of surface materials from the last glaciation such as alluvial, lacustrine, marine, and glacial; also includes eskers, moraines, and drumlins.

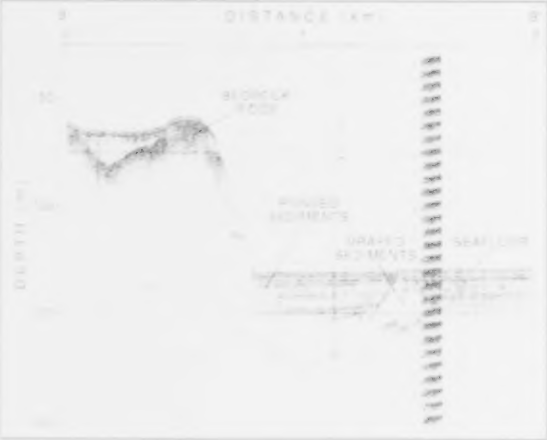

Figure 3-12. **Thick sediment sequence deposited in a bedrock low just seaward of Little Whale River (from Josenhans et al. 1991).**

Seafloor disturbance by grounded ice has been restricted to the nearshore areas of less than 20 m since deglaciation, so the seafloor morphology preserved over most of Hudson Bay is a good indicator of the glacial and deglacial processes that occurred during the final disintegration of the Laurentide Ice mass (Josenhans and Zevenhuizen 1990). Indeed, slide scar and gravity-flow deposits in the sediment of Manitounuk Sound suggest that there was intense earthquake activity in that region due to stress release along faults during or shortly after deglaciation (Hill et al. 1999). The interpretation of microfloral and microfaunal assemblages in these sediments can provide a useful record of post-glacial conditions in the marine environment (Bilodeau et al. 1990). There are many distinctive and well-preserved glacial landforms on the floor of Hudson Bay that evidence this rapid transition (Josenhans and Zevenhuizen 1990).

Sediments in Hudson Bay grade from coarse Precambrian or Paleozoic gravels nearshore, to fine silt and clay with considerable organic carbon content offshore (Pelletier et al. 1968; Pelletier 1969, 1986). Coarse sediments are rare offshore except for the relatively shallow Midbay Bank, which contains sand, gravel, and blocks of carbonate bedrock. Fluvial-sediment distribution may be obscured by the scouring action and sediment contributions of drift ice. Some coarse materials are frozen into the coastal ice and deposited wherever the ice melts. The composition of these ice-rafted sediments depends largely on the type of bedrock along the coast. How much of the coarser bottom material is pre-glacial in origin is unknown.

The role of shore ice and freeze-thaw processes in intertidal sediments has been studied along the inner shoreline of Manitounuk Sound (Allard et al. 1998; Figure 3-13). Shoreline dynamics in the area are controlled not primarily by mechanical processes, such as ice scour or clast transport, but by the thermal behaviour of the ice foot and the control that it exerts on surface and groundwater flow in winter. As the ice foot freezes to the surface of the tidal flat, a freezing front penetrates up to 3 m into the underlying sediments. This destroys the structure of the clays and leads to their liquefaction in early summer. It also impedes groundwater and surface-water flow, causing seepage and ice build-up in the upper tidal zone. Melting of all this ground ice causes settlement, microcliff collapse, and mud flows. Rather than being a typical tidal flat, the Manitounuk tidal zone is

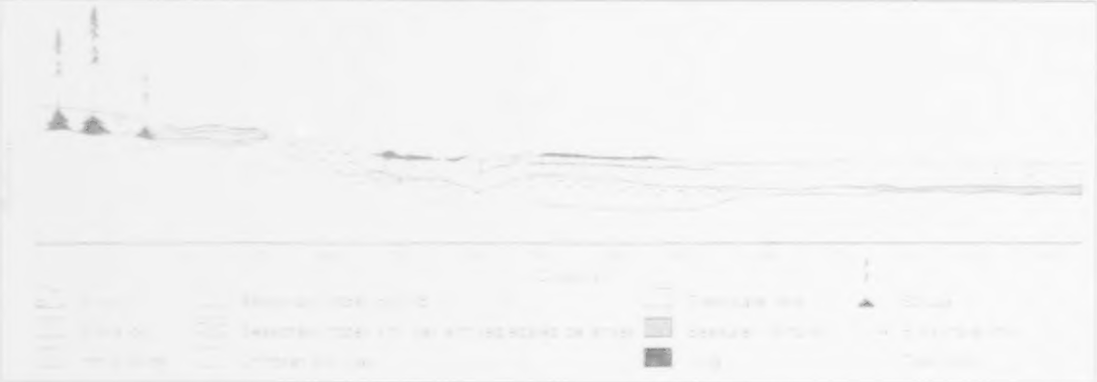

Figure 3-13. **Schematic cross section (vertical scale approximate) showing the winter distribution of frozen ground and ice masses in the coastal zone of Manitounuk Sound, with inferred groundwater pathways (from Allard et al. 1998).**

an erosional platform that is cut in soft Quaternary sediments and graded by waves and tides that remove sediments from the tidal zone. This platformal erosion is the main source for sediment deposition in the shallow waters of Manitounuk Sound. It also plays an important ecological role by preventing the colonization of the coastal zone by molluscs and restricting the extent of coastal marshes. These processes may play an important role along other coasts of the Hudson Bay marine ecosystem.

Studies of bottom topography and composition in Hudson Bay have largely missed the James Bay marine region (Pelletier et al. 1968; Pelletier 1969, 1986, Josenhans et al. 1988; Henderson 1989). It is only recently, with interest in the coastal effects of hydroelectric developments, that some areas have received attention--notably northern James Bay (Kranck and Ruffman 1982) and the area offshore Grande rivière de la Baleine (Josenhans and Zevenhuizen 1990; Josenhans et al. 1991). Detailed data on bottom topography and geology are available for narrow corridors between Grande rivière de la Baleine and the Belcher Islands, and along the Hudson Bay coast between Grande rivière de la Baleine and Petite rivière de la Baleine.

Most modern sediments enter Hudson Bay and James Bay in runoff and are dispersed counter-clockwise along the coastal shelf by currents (Pelletier et al. 1968; Pelletier 1969, 1986). James Bay receives an estimated 4.12×10^7 metric tons per year, of which 66% is derived from the western side and only 34% from the eastern Precambrian terrain (Kranck and Ruffman 1982). To put this in perspective, James Bay (not including southeastern Hudson Bay) receives 44% of the water from the combined Hudson and James Bay drainage basin, but contributes 63% of the combined sediment load. Indeed, it receives river borne sediment equal to about one-half of the total load carried by all Canadian rivers emptying into the Atlantic Ocean, including the St. Lawrence.

Much of the sediment entering James Bay is deposited in the nearshore zone, but there may be a zone of minimum deposition between the nearshore deltaic and tidal flat deposits and the deepwater mud blanket (Kranck and Ruffman 1982). Little of the suspended material is deposited in deltas at the river mouths and sand found there is derived mainly from the erosion of emerged deltas in the coastal plain (Meagher et al. 1976 in Dionne 1980a). Most river-borne sediment is dispersed along the coasts either by tides, longshore currents, or ice rafting (King and Martini 1984). Relatively high turbidity values in the bay indicate that appreciable amounts of sediment are being transported in the fresher surface waters (Kranck and Ruffman 1984).

Mud bottom occurs over most of James Bay, with sediment dominated by sand and gravel occurring only in the vicinity of the central high and along the eastern shore (Kranck and Ruffman 1982). Underwater photographs show the bottom of Omarolluk Sound in the Belchers to consist of fine materials such as clay and silt (Barber et al. 1981). Quiet deposition is indicated by the absence of coarse sediment, scour, and wave-built materials.

3.5 SUMMARY

The Hudson Bay marine ecosystem and its coasts are situated on Precambrian Shield rock that is overlain, except in eastern James Bay, along the Québec coast of Hudson Bay and the west coast north of the Knife Delta, by thick sequences of platformal sedimentary rock. Two geological provinces of the Shield are represented. The Superior Province underlies eastern James Bay and forms most of the Québec coast from the Nottaway River north to Korak Bay; the Churchill Province underlies southeastern Hudson Bay, the Québec coast in the Richmond Gulf area and north of Korak Bay, and the west coast north of Churchill. The older crystalline, sedimentary, and volcanic basement and plutonic rock of The Shield is often deformed and (or) metamorphosed. The younger, calcareous rock of the Hudson Platform is generally flat-lying or little deformed. Most of the bedrock is covered by unconsolidated materials or by wetlands, except along the northern Hudson Bay coasts of Québec and Kivalliq.

This region was glaciated most recently by the Laurentide Ice Sheet, which was composed of glaciers that emanated from centres around, rather than in, Hudson-James Bay. Thick ice covered the entire marine area including the coasts, and affected most of its' present day features. Ice loading depressed the earth's surface so that the present-day coast was inundated by marine waters following glaciation. Subarctic oceanographic conditions, which persisted between about 6500 and 4000 yBP, were likely responsible for the relict Subarctic species that inhabit James Bay and southeastern Hudson Bay. Isostatic rebound continues at a rate of 0.7 to 1.3 m per century, so that most coastlines exhibit a variety of emergent glacial deposits. The southern extent of continuous permafrost along the region's coasts is unusual and strongly affects many other coastal themes such as soil development and shoreline vegetation.

There are three basic coastal types: low-lying, cliff and headland, and complex. The recently emerged, low-lying coastal sections occur more or less continuously from Arviat in Nunavut to the Conn River in Québec; on the larger islands of James Bay; and along the southwestern shores of islands in northern Hudson Bay. Characterized by very gradual seaward slopes, they have shallow nearshore waters and extensive tidal flats that give way inland to low-lying, marshy coastal plains. Large rivers carrying much of the freshwater runoff that enters the marine ecosystem dissect the low-lying coastline (e.g., Nelson, Churchill, Albany, Moose, Nottaway). Access to and from the water along its shallow shores can be difficult and coastal travel in small craft is dangerous when winds rise. Most of the surface material is unconsolidated, and the coastal landscape evolves from one dominated by coastal landforms to one dominated by organic landforms. The extensive salt marshes and tidal flats provide vital habitat for many migratory waterfowl and shorebird species. They are one of the best examples of a fast-emerging, flat-lying shoreline in the world.

Well developed cliff coasts and headlands occur in Québec near Cape Smith and around most of the Hudson Bay Arc; along the mainland coast of Nunavut from Rankin Inlet to Chesterfield Inlet, Daly Bay to south of Wager, inside Wager Bay, and around Repulse Bay; and on the Ottawa and Belcher islands, White Island, and northeastern Southampton Island. In the Hudson Bay Arc elevations can reach 500 m and local relief 100 m, exposed bedrock is common, and tidal flats are lacking. Offshore, Manitounuk Island and the Nastapoca Islands are typical bold cuesta formations with low relief on the west side and steep slopes on the east. These formations are associated with broadly developed fault systems and fold blocks, and show a distribution similar to that of submerged canyons and cliffs. Local relief along the Nunavut coast between Rankin and Chesterfield inlets, and around Repulse Bay, seldom exceeds 30 m. South of Chesterfield Inlet, unconsolidated materials including well-developed networks of eskers are common and there are small tidal flats, marine spits and some rock. Gently rolling hills of Precambrian bedrock, often overlain by marine deposits that support tundra vegetation, form the coastline in the Repulse Bay area. Inside Wager Bay, on White Island and along the northeastern coast of Southampton Island the coastal terrain can be very rugged with steep cliffs rising abruptly 300 to 500 m asl and local relief >50 m. Elevations seldom exceed 200 m asl in the Belcher and Ottawa islands, where relief is generally low and the coastline rocky. Gilmour Island, which rises abruptly to 300 m asl is an exception. Continuous permafrost underlies the surface except along the Hudson Bay Arc and in the Belcher and Ottawa islands, where it is discontinuous. These coastlines are dry relative to the low-lying coasts, with decreasing organic cover and vegetation moving northward and on the islands, and a shallow active layer of soil that is often rocky. Trees occur north to about 57°10'N along the east coast but are absent elsewhere. These coasts have superb examples of emergent features, particularly the flights of raised marine beaches. They also support important cliff-nesting bird species that are not common elsewhere in the marine ecosystem. Grande rivière de la Baleine is the only major river that dissects the cliff and headland coastlines.

Elsewhere in the region, bedrock folding, volcanism, and differential erosion of the exposed rock have created an intricate coastline of small headlands and bays. In Nunavut and along the Québec coast north of Inukjuak, local relief in these coastal sections is generally <30 m and rocky shores are common. The surface is a mixture of exposed bedrock and unconsolidated materials, underlain by continuous permafrost. The active layer of soil is shallow but supports tundra vegetation; it is often rocky and may have barren areas. The terrain is typically well drained, relative to the low-lying coasts. Small tidal flats occur around many of the small bays and islands. In northeastern James Bay these coastlines are extremely irregular in shape and fringed by a myriad of small islands, skerries, and shoals. The surface is locally covered by thin glacial drift and emerged coastal deposits. There is little local relief and permafrost grades from sporadic near Kuujjuarapik to isolated in southern James Bay; soils are better developed and support trees. Tidal flats, some of them fringed inland by wide salt marshes, are found in most large embayments and around most offshore islands, and there are vast subtidal meadows of eelgrass (*Zostera marina* L.). Major rivers that dissect the complex coasts include the Eastmain, La Grande and Povungnituk in Québec, and the Thelon and Kazan in Nunavut. These coastlines provide the greatest variety of landforms and biological habitats. Their tidal flats, coastal salt marshes, and subtidal eelgrass meadows have particular ecological importance.

Hydroelectric developments have profoundly altered the hydrology--particularly the volume and seasonality of flow, of the Churchill and Nelson rivers in Manitoba and the Eastmain, Opinaca and La Grande rivers in Québec. Ontario's Moose River is also affected but to a lesser degree. The Nottaway, Broadback and Rupert rivers in Québec may be affected by future hydroelectric development. The effects of these developments on the marine ecosystem are discussed in Chapter 15.

Bedrock and pre-glacial erosion have had a profound influence on shaping this region's bottom topography, and the submarine geology and physiography tend to be extensions of coastal formations and features. Hudson Bay has a wide coastal shelf that slopes gradually to a relatively shallow seafloor, and sediments that grade from coarse gravels nearshore to fine silt and clay offshore. The Hudson Bay Arc area differs from the rest of Hudson Bay and James Bay in having exceptional, perhaps unique, enclosed bathymetric deeps (>200 m depth) that resemble the adjacent cuesta coastline. James Bay is seldom deeper than 50 m and extremely shallow for such a large marine area. The bottom sediment distribution is controlled primarily by the Late Wisconsin glaciation. The cover is generally thin and consists primarily of till or fine-grained glaciomarine deposits.

4.0 CLIMATE

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The Hudson Bay marine ecosystem is abnormally cold relative to other areas at the same latitude and exerts a strong influence on the surrounding land, contributing in particular to the unusual southern extent of the permafrost (Thompson 1968; Danielson 1969; Maxwell 1986; EWG 1989). The Kivalliq coast, in particular, is known for its strong winds and persistent low temperatures. Indeed, the region's earlier name "Keewatin" means "land of the north wind" in Inuktitut (Danielson 1969), and Chesterfield Inlet on the northwest coast has some of the most extreme wind chills in Canada. Coastal areas, with Hudson Bay on one side and treeless tundra on the other, are particularly exposed.

Most of our understanding of weather over the marine ecosystem has been inferred from coastal data. This biases some inferences. Land-based wind measurements, for example, tend to underestimate winds over the ice and water. Larouche (1990), who conducted winter studies at Kuujjuarapik, found the mean wind speed was 29% higher over landfast ice and 66% higher over open water than at the coast.

Journals maintained by employees of the Hudson's Bay Company Posts contain daily references to the weather that date back to at least 1715 at Churchill and 1720 at York Factory and in James Bay (Catchpole and Ball 1981; Ball 1985). These systematic records provide useful data for long-term climatic comparisons (e.g., Moodie and Catchpole 1975; Catchpole 1980, 1985; Catchpole and Ball 1981; Jacoby and Ulan 1982; Catchpole and Faurer 1985; Wilson 1985a+b). Development of a comprehensive network of weather observing stations along the shores of Hudson Bay was not begun until 1931 (Thompson 1968). Its' purpose was to provide weather information and navigational assistance to ships using the northern sea route to transport grain and other goods from Churchill, through Hudson Bay and Hudson Strait, to European markets. Comprehensive, systematic weather data have been collected longest at Churchill, since 1931 at Inukjuak, Kuujjuarapik and Chesterfield Inlet, since 1932 at Moosonee, 1941 at Chisasibi, and since 1943 at Coral Harbour. Shorter periods of observation are available for other communities bordering the ecosystem. Shipboard observations have provided a modest data set of offshore weather observations that allows comparison between coastal and offshore conditions during the navigation season (EAG 1984; Prinsenberg and Danard 1985; Maxwell 1986; Cohen et al. 1994)--late July through mid-October (Jones 1968). These data are not evenly distributed over the region. Few data are available from offshore areas outside the navigation season, and we know of no offshore precipitation records.

This section provides general historical background information on the climatic features that affect Hudson Bay and James Bay. As such, it does not discuss linkages with oceanographic processes or the wide variability of climatic components. That comes later. The impacts of climate on key physical and biological oceanographic processes, such as circulation, ice formation and production are discussed in Chapter 5 (Oceanography), and in the other Chapters that follow. The dynamic nature of the climate system as it affects the Hudson Bay marine ecosystem is discussed further in Chapter 17 (Climate Change). Unless otherwise noted the following treatment of climate draws on studies prepared by Thompson (1968), Danielson (1969), Fletcher and Young (1976), and Maxwell (1986). Data presented are taken from the 1951-80 normals period where available (after Maxwell 1986). More recent data on the 1971-2000 normals period are available from Environment Canada ([illegible]).

4.1 CLIMATE CONTROLS

The climate system is an interactive system consisting of five major components: the atmosphere, the hydrosphere, the cryosphere, the land surface, and the biosphere, influenced by various external forces (Figure 4-1). The most important of these forcing mechanisms is the Sun but human activities also have a direct forcing effect on climate (Figure 4-2).

To understand the climate of the marine ecosystem one must consider the basic climatic controls such as distance from the equator, the nature of adjacent surfaces, continental and maritime influences, and the major features of atmospheric and hydrospheric circulation. The effects of human activities on climate are discussed in Chapter 17.

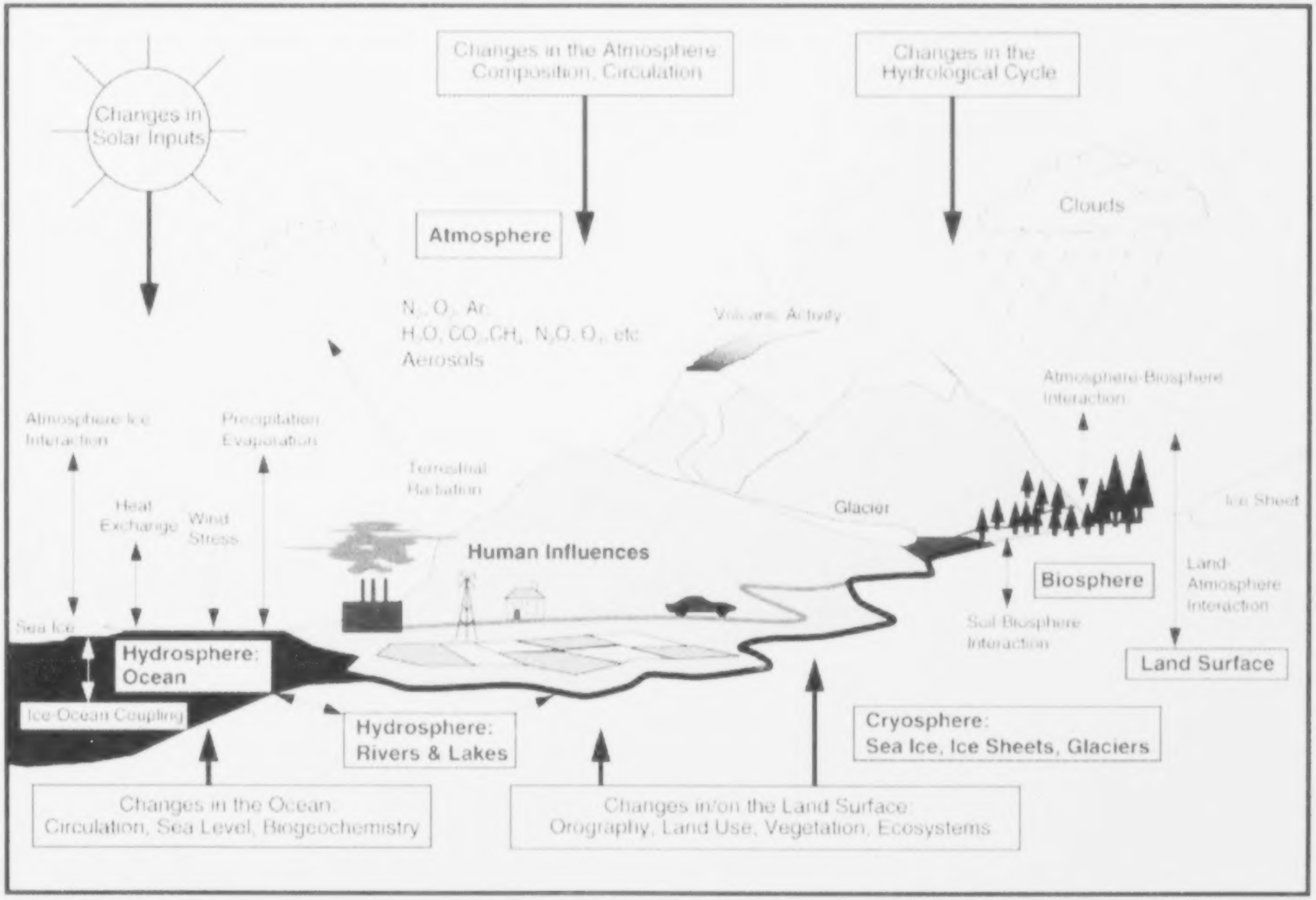
Changes in Solar Inputs
Changes in the Atmosphere: Composition, Circulation
Changes in the Hydrological Cycle
Atmosphere
Clouds
N_2, O_2, Ar
H_2O, CO_2, CH_4, N_2O, O_3, etc
Aerosols
Volcanic Activity
Atmosphere-Ice Interaction
Precipitation Evaporation
Heat Exchange
Wind Stress
Terrestrial Radiation
Atmosphere-Biosphere Interaction
Glacier
Ice Sheet
Human Influences
Biosphere
Land-Atmosphere Interaction
Sea Ice
Hydrosphere: Ocean
Soil-Biosphere Interaction
Land Surface
Ice-Ocean Coupling
Hydrosphere: Rivers & Lakes
Cryosphere: Sea Ice, Ice Sheets, Glaciers
Changes in the Ocean: Circulation, Sea Level, Biogeochemistry
Changes in/on the Land Surface: Orography, Land Use, Vegetation, Ecosystems

Figure 4-1. **Schematic view of the components of the global climate system (bold), their processes and interactions (thin arrows) and some aspects that may change (bold arrows) (from IPCC 2001).**

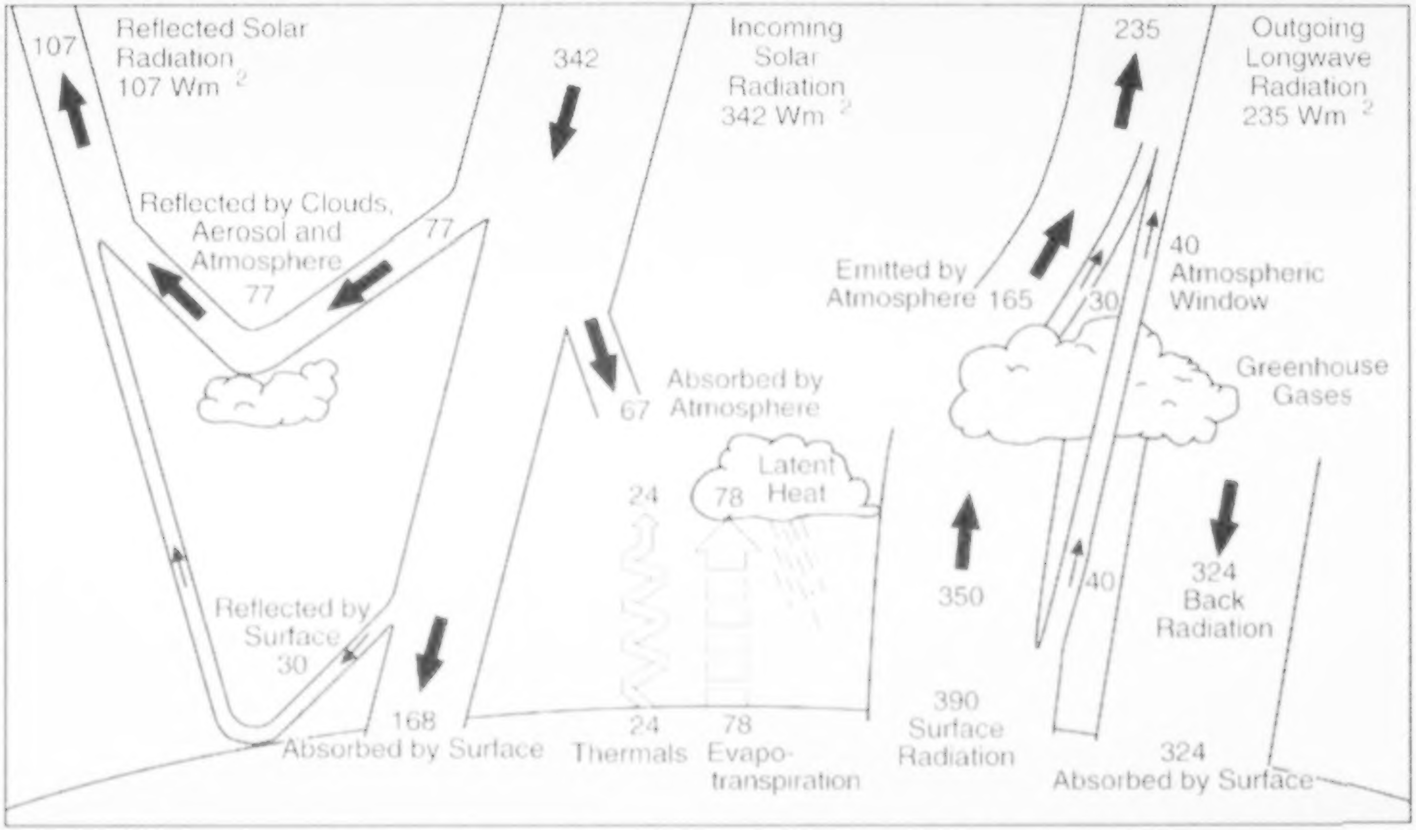

Figure 4-2. The Earth's annual and global mean energy balance. Of the incoming solar radiation, 49% (168 W·m^{-2}) is absorbed by the surface. That heat is returned to the atmosphere as sensible heat, as evapotranspiration (latent heat) and as thermal radiation. Most of this radiation is absorbed by the atmosphere, which in turn emits radiation both up and down. The radiation lost to space comes from cloud tops and atmospheric regions much colder than the surface. This causes a greenhouse effect. (from IPCC 2001 after Kiehl and Trenberth 1997).

4.1.1 Radiation Regime

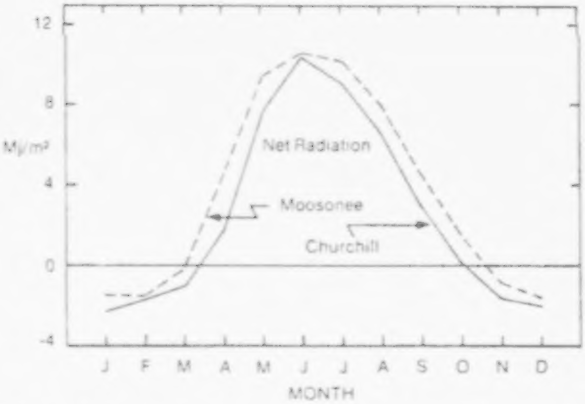

Figure 4-3. **Mean daily net radiation at Moosonee and Churchill (from Maxwell 1986).**

While the Hudson Bay marine ecosystem is situated well south of the Arctic Circle, there is a large seasonal variation in incoming solar radiation, and the percentage of that radiation reflected (albedo) by snow, ice, wet surfaces, fog, and cloud is high (see also Wilson 1976; Lafléur et al. 1987; Rouse et al. 1989; Silis et al. 1989). At Churchill and Moosonee the mean daily net radiation is positive from mid-March through October and negative for the remainder of the year (Figure 4-3). The highest mean daily net radiation occurs from May through August when solar radiation is greatest, despite the high surface albedo, and warm air over the cold water or ice keeps long-wave heat loss to a minimum. Solar heating decreases thereafter while long-wave and turbulent heat losses increase. The lowest mean daily net radiation occurs in December and January when solar heating is least and long-wave heat losses are greatest. Long-wave heat losses that continue though the winter allow ice cover to reach its' maximum in April at Churchill and in late March at Moosonee (Bilello 1980; Markham 1986, 1988), after which there is a sharp increase in solar radiation.

4.1.2 Nature of Immediate and Adjacent Surfaces

Ice cover or very cold surface waters are characteristic of the Hudson Bay marine ecosystem except at the height of summer. In winter, ice cover causes its surface to experience the same climate as the adjacent coast. Ice and snow drastically reduce light penetration to the water, and thereby marine productivity. In summer, the cold Arctic water limits air temperatures in the immediate coastal areas to little more than 5 or 7°C over the temperature of the water and contributes to the presence of permafrost well past its normal southern latitude (Figure 3-7). Permafrost affects the summer climate, particularly that of western Hudson Bay and northwestern James Bay, by preventing moisture penetration into the soil. The resultant evaporation consumes energy that might otherwise be available to increase air temperatures.

4.1.3 Physical Geography

While it is exposed to cold Arctic air masses year-round and to occasional intrusions of warm air from the south in summer, the Hudson Bay marine ecosystem is buffered from the direct entry of air masses from the Pacific and Atlantic oceans by mountains and distance. There are no major topographical features near the coast, but the inshore islands and coastline of southeastern Hudson Bay rise to elevations of 500 m asl in some areas. These heights of land act to modify climate on their leeward sides. The lack of major topographical features elsewhere means that other local coastal climates are often dependant on variations in terrain, vegetation, or drainage.

4.1.4 Circulation and Weather Systems

The upper-air circulation controlling movement of weather systems over the water is mainly related to the persistent, counter-clockwise air flow around a low pressure vortex or trough (polar vortex) which is situated over Baffin Island in winter but weakens and retreats northward in summer. In winter there is a general flow of cold Arctic air from the northwest or west over the western half of Hudson Bay and from the west or southwest over James Bay and eastern Hudson Bay. Low-pressure areas generally pass south of James Bay but can induce strong surface winds from the north or northwest as they recurve northward over Davis Strait. In spring the cold marine water has a stabilizing effect on the air. Its cooling effects reduce vertical convection and thereby wind stress and evaporation, and increase the heat flux into the water (Prinsenberg and Danard 1985). In summer there is a general, but less intense, flow of air from the west through to the north (EAG 1984) over the water that exerts a moderating influence on the eastern coast. Summer storms often move directly across central Hudson Bay from the west or southwest, and thunderstorms are common on the Belcher Islands in summer. Currents of relatively warm, moisture-laden air from the south frequently precede these low-pressure areas. In autumn the relatively warm waters have a destabilizing effect on the cooler air, and the west to east storm tracks move southward to cross James Bay.

The position and intensity of the trough strongly influence year-to-year variability of the region's climate and affect the timing of ice breakup and freezeup (Cohen et al. 1994; Wang et al. 1994c; Mysak et al. 1996; Mysak and Venegas 1998). A more intense trough or an eastward shift in its position brings cold northerly air into the region more frequently, and *vice versa*. These shifts can occur in a very short time, forced primarily by natural variation in the atmospheric pressure field associated with the Arctic Oscillation (Macdonald et al. 2003a).

The Arctic Oscillation is an atmospheric circulation pattern in which the atmospheric pressure over the polar region varies in opposition with that over middle latitudes (about 45 degrees North) on time scales ranging from weeks to decades. It extends through the depth of the troposphere and from January through March upward into the stratosphere, where it modulates the strength of the westerly vortex that encircles the Arctic polar cap (http://nsidc.org/arcticmet/). The Arctic Oscillation correlates strongly (85-95%) with the North Atlantic Oscillation, a more commonly used indicator of large-scale wind forcing. The latter is the normalized gradient in sea-level air pressure between Iceland and the Azores. The terms carry much the same information and can be used more or less interchangeably (Macdonald et al. 2003a). When the Arctic Oscillation is in its "negative phase", pressure is higher over the polar region than at mid-latitudes and frigid winter air extends further south—and *vice versa* (Figure 4-4).

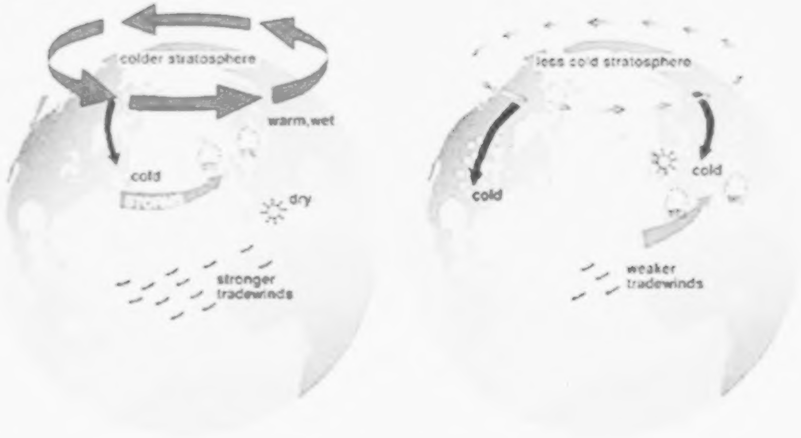

Figure 4-4. **Effects of the positive (left) and negative (right) phases of the Arctic Oscillation (Figure from the NSIDC Arctic Climatology and Meteorology Primer, attributed to J. Wallace, University of Washington [http://www.nsidc.org/arcticmet/]).**

The effects of these large-scale changes in atmospheric pressure on the Hudson Bay marine ecosystem are not fully understood (Macdonald et al. 2003a). However, both the North Atlantic Oscillation and the El Nino-Southern Oscillation have been correlated with decadal changes in the concentration of the sea ice (Wang et al. 1994c; Mysak et al. 1996; Mysak and Venegas 1998). During strong winter westerly winds of the

North Atlantic Oscillation and Low/Wet summer episodes of the El Nino-Southern Oscillation, thicker sea ice forms in Hudson Bay and breakup is delayed.

Atmospheric pressure systems also influence water circulation in Hudson Bay directly by wind stress and indirectly by tilting the sea surface (Larouche and Dubois 1988, 1990). Changes in the direction and amplitude of surface currents in the spring near Kuujjuarapik correlate well with direct wind action, with a lag time of hours or days depending upon the strength of the changing wind; the effect of surface tilting is small by comparison.

4.2 SEASONS

Seasons in the Hudson Bay marine ecosystem do not correspond exactly to those in southern Canada or in Foxe Basin, and vary from north to south. In northern Hudson Bay, autumn usually lasts from early September through October; winter from November to the end of April; spring through May and June; and summer through July and August. In southern Hudson Bay and James Bay, autumn usually lasts from mid-September through mid-November; winter from mid-November to the end of March; spring from April through mid-June; and summer from mid-June to mid-September. The following sections briefly describe seasonal changes in temperature, wind, precipitation, and the frequency of fog and blowing snow.

4.2.1 Autumn (mid-September to mid-November in the south; September to October in the north)

In autumn the cold Arctic air masses move progressively southward as the days shorten and upper-air westerlies intensify, until by October the main west to east storm tracks cross Hudson Bay and northern James Bay at 3 to 4 day intervals (Figure 4-5 and Figure 4-6) (see also EAG 1984). The heat and moisture they

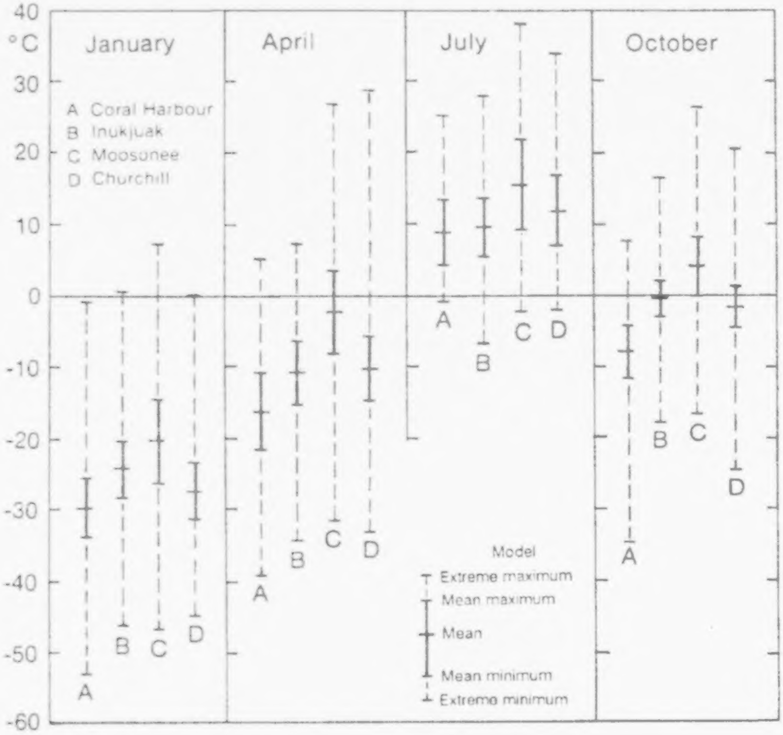

Figure 4-5. **Mean annual and extreme air temperatures at Coral Harbour (A), Inukjuak (B), Moosonee (C) and Churchill (D) (from Maxwell 1986).**

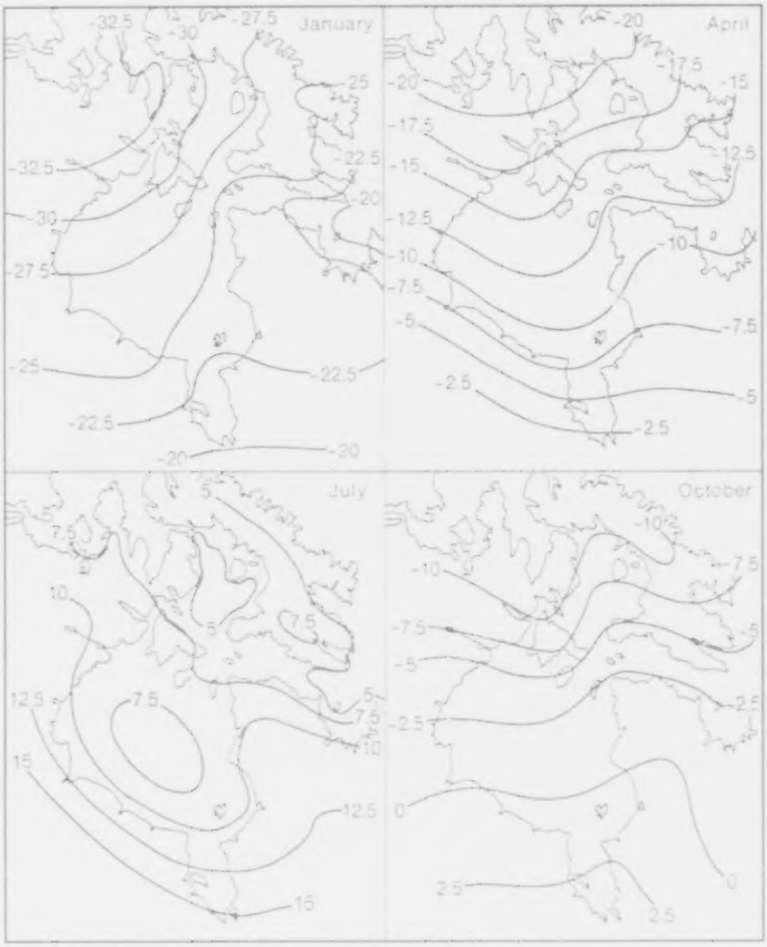

Figure 4-6. **Mean daily air temperature (°C) (from Maxwell 1986).**

accumulate in passing over the still-open waters result in cloudiness and snowfall (Figure 4-7), particularly along the southeastern coast. In Hudson Bay, the prevailing autumn winds are generally northwesterlies except in the southeast where the last remaining open water surface is reflected by frequent easterly winds at Kuujjuarapik. The surface wind speed averages about 20 to 25 $km \cdot h^{-1}$ – a bit higher in Hudson Strait and lower in James Bay (Table 4-1). On average the mean daily temperature drops below 0°C in late September at Coral Harbour and in late October at Moosonee (Markham 1988). Low-lying cloud and fog are common. The wind velocities, frequency of fog, and mean total cloud cover are expected to be greater over the smoother, moister marine surface than on the coasts (see also EAG 1984).

In northern and western Hudson Bay the stormiest months with the highest surface winds and snowfall occur in late fall (October) and early winter (November), a bit later in James Bay (Table 4-1; see also EAG 1984). During this period, turbulence, poor visibility caused by snowstorms, and severe icing in low-lying cloud hampers air travel to communities along the northern coasts of Hudson Bay. Strong autumn winds can cause tidal storm surges of at least 1.2 m in southern James Bay--sometimes with fatal consequences (Godin 1975). Coastal boat travel is also hampered by strong winds, fog, superstructure icing (see also EAG 1984), and coastal ice formation. Local coastal travel by snowmobile begins soon after the landfast ice begins to form, usually in late November in the north and early December in the south, but is not widespread until about mid-

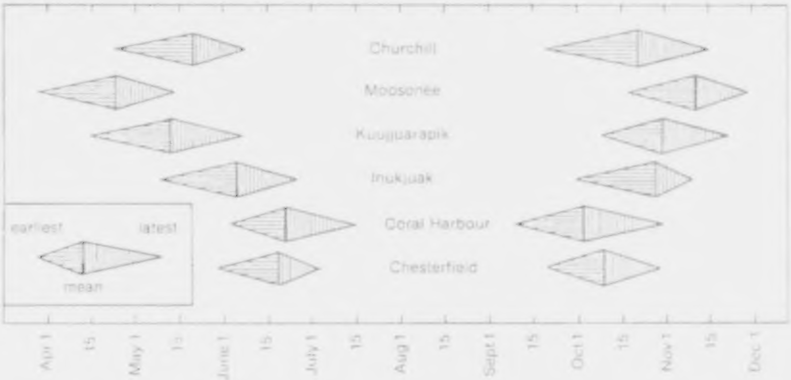

Figure 4-7. **Disappearance and formation dates of continuous snow cover (from Maxwell 1986).**

December in the north and late December in the south when the ice is stronger and extends well down the east and west coasts.

4.2.2 Winter (mid-November to March in the south; November to April in the north)

Cold conditions that persist over long periods and frequent, severe wind chill are characteristic of the Hudson Bay marine ecosystem in winter, particularly along the barren northwestern coast. To the south the winters are long and cold but not as severe, especially in southern James Bay where forests offer protection from the wind. The shortest day of the year, 21 December, is about 8 h 24 min in the south and 4 h in the north (Canada 1987). Temperatures less than -15°C persist for much of the time and thaws are infrequent. Extreme low temperatures in the -45° to -50°C range, about 5°C cooler in northern Hudson Bay, generally occur in January or February (Figure 4-5, Figure 4-6).

The relatively warm water has a moderating influence on air temperatures along the leeward east coast of the ecosystem, particularly before ice formation is completed in mid-December (Markham 1986, 1988). Afterwards, the marine surface resembles that of the adjacent land and cloud, snowfall, and temperature regimes show less west-to-east variation.

During the winter, the main storm tracks lie south of James Bay. The winds are constant due to a strong pressure gradient between the high over the Mackenzie-Kivalliq area and low over the Baffin Bay-Davis Strait area. Most of the bad weather results from temporary changes in the direction of upper wind flow, which causes southern storms to deviate northward, or from fluctuations in the pressure gradient. The former may bring clouds, snow and wind, and the latter strong wind. Closer proximity to the storm tracks results in greater cloud cover along the southern coast, and localized steam fog occurs at persistent shore leads and wind-induced patches of open water.

Characteristic features of the winter weather in northern and western Hudson Bay are strong winds, persistent low temperatures, and snow cover (Table 4-1; Figure 4-5, Figure 4-6 and Figure 4-8). In combination, the average January wind speeds, 20 to 25 $km\cdot h^{-1}$, and temperatures, -25 to -30°C, in coastal areas correspond to a cooling rate (wind chill) of nearly 2300 $watts\cdot m^{-2}$, a level at which exposed skin freezes in less than a minute for the average person. Wind chill at Chesterfield Inlet can reach 3118 $watts\cdot m^{-2}$ in January and is at the extreme for all of Canada. The snow is generally fine and powdery. It is carried easily by the strong winds and frequently restricts visibility (Table 4-1). Blizzards caused by strong winds, low temperatures,

Table 4-1. Monthly and annual wind speed, precipitation, and frequency of fog or blowing snow, 1961-80 normals (from Maxwell 1986; tr = trace amount).

		Feb.	Apr.	Jun.	Aug.	Oct.	Dec.	Annual
Wind speed (km·h^{-1})								
Moosonee	mean	12.2	14.5	14.1	12.3	14.4	11.8	13.5
	maximum	60	51	45	48	56	56	61
Kuujjuarapik	mean	16.9	17.0	16.7	17.9	21.2	20.4	18.3
	maximum	74	80	64	77	80	84	97
Inukjuak	mean	17.2	32.6	20.8	21.6	22.4	20.8	21.2
	maximum	59	74	52	61	65	63	74
Churchill	mean	24.1	22.6	20.7	20.5	24.9	22.4	22.7
	maximum	80	74	77	95	82	80	116
Chesterfield Inlet	mean	24.6	21.4	18.5	20.4	27.9	23.8	22.3
	maximum	80	78	93	70	95	74	95
Coral Harbour	mean	20.2	19.3	19.6	19.8	22.1	20.5	20.2
	maximum	135	93	74	97	90	109	145
Mean precipitation								
Moosonee	rain (mm)	1.8	21.4	77.9	79.2	60.2	3.9	501.5
	snow (cm)	30.0	21.2	0.8	0.0	14.5	39.9	239.3
Kuujjuarapik	rain (mm)	0.3	5.2	51.7	94.0	46.3	1.0	401.3
	snow (cm)	24.2	22.1	4.8	0.0	27.3	42.0	241.2
Inukjuak	rain (mm)	0.0	1.9	31.1	64.9	24.4	0.1	246.3
	snow (cm)	6.7	13.3	3.7	tr	22.0	23.2	144.2
Churchill	rain (mm)	0.1	2.0	39.9	58.3	15.4	0.2	221.1
	snow (cm)	14.6	22.3	3.5	0.0	29.3	22.8	195.5
Chesterfield Inlet	rain (mm)	0.0	4.0	17.9	38.6	9.4	tr	145.5
	snow (cm)	4.5	11.5	5.1	0.2	24.3	13.6	112.5
Coral Harbour	rain (mm)	tr	tr	18.5	44.2	11.3	tr	141.4
	snow (cm)	9.2	14.4	8.1	0.3	26.7	10.6	131.9
Frequency of fog or blowing snow (mean number of days)								
Moosonee	fog	1	2	1	2	1	1	17
	blowing snow	4	1	<1	0	<1	3	18
Kuujjuarapik	fog	1	3	8	9	1	1	45
	blowing snow	7	5	<1	0	3	10	62
Inukjuak	fog	1	3	7	9	3	1	46
	blowing snow	9	8	*	0	2	11	62
Churchill	fog	2	4	8	8	4	1	48
	blowing snow	11	5	*	0	4	10	64
Chesterfield Inlet	fog	1	3	5	6	4	2	42
	blowing snow	11	7	*	0	5	10	72
Coral Harbour	fog	3	2	5	5	5	2	44
	blowing snow	9	8	1	0	5	9	64

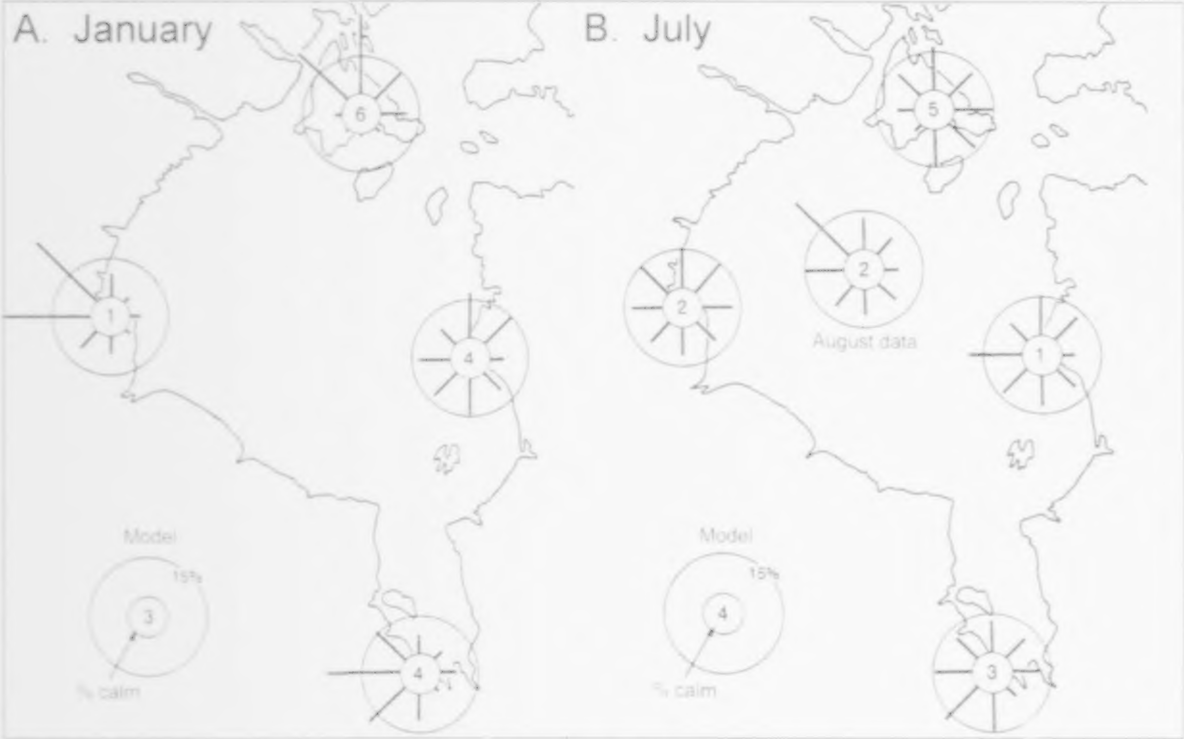

Figure 4-8. Percentage frequency of wind occurrence by direction in January (A) and July (B) (from Maxwell 1986).

and falling snow make outdoor human and animal activity impossible--blowing snow can maintain blizzard conditions long after the snowfall. In northwestern Hudson Bay, blizzard conditions occur 5 to 7 percent of the time in January and February--less often further south. During winter much of the initial snowfall in the Churchill area is blown off the sea ice and tundra and accumulates in the woodlands (Scott et al. 1993).

Southeastern Hudson Bay and James Bay also experience the persistent low temperatures and snow cover but not the extreme wind chills and frequent blizzards characteristic of the west coast of Hudson Bay. Despite this, the average January wind speeds of 15 to 20 km·h^{-1} and temperatures of -20 to -25°C in coastal areas do correspond to a cooling rate (wind chill) of 1600 to 1900 watts·m^{-2}, at which exposed skin freezes in less than a minute for the average person. Maximum cooling rates generally occur in January and range from about 2800 watts·m^{-2} in the north to 2500 watts·m^{-2} in the south. The snow is soft and deep in the coastal forests, but drifted and hard packed over the exposed sea ice. Southern coasts receive considerably more snow than those in the north but are snow covered for a shorter period (Figure 4-7). Blizzards occur less often in the south.

4.2.3 Spring (April to mid-June in the south; May to June in the north)

Spring is late and cool relative to southern Canada. It is characterized by rapidly lengthening daylight hours, above-freezing temperatures, and snowmelt. Warm southern air masses gradually penetrate further northward, increasing temperatures and storm frequencies. Low-lying clouds and fog are common as the snow and ice begin to thaw (Figure 4-7) and travel on the sea ice becomes increasingly difficult with runoff and surface melting. On average the mean daily temperature exceeds 0°C beginning in late April at Moosonee and in early June at Coral Harbour (Markham 1988). The longest day of the year, 21 June, is about 16 h 35 min. in the south and 21 h in the north (Canada 1987).

4.2.4 Summer (mid-June to mid-September in the south; July and August in the north)

Summer extends from the time snowmelt is complete until the first snow flurries of autumn. Because Hudson Bay remains frozen or is dominated by ice cover over the summer solstice and throughout much of the high-sun season, it has a strong cooling effect on the surrounding terrestrial environments during the summer. Rouse (1991) described it as the "winterization of summer".

During July and August the temperatures are lower on the eastern coasts of James Bay and Hudson Bay than on the western coasts, due mainly to the cooling westerly winds over the partially ice-covered waters. Freezing temperatures have been recorded during every month of the year along the entire coastline. Temperatures are generally cooler over the water—typically from 1°C in the north to 10°C in the south (see also Gachon et al. 2002), and extreme coastal temperatures are in the range of 30 to 38°C (Figure 4-5 and Figure 4-6). Sharp temperature inversions are common as warm air moves over the cold water and the lower air is cooled. These shallow, low-level inversions increase the near surface atmospheric stability over the bay. They affect humidity, temperature and wind profiles, as well as low-level clouds and radiation, which in turn control the seasonal oceanic heating of the mixed layer (see also Gachon et al. 2002). Warm air masses passing over the cooler water result in extensive fog and cloud coverage both over the water and along the coasts, depending upon wind direction. Fog is very common along the southeastern Hudson Bay coast where the prevailing summer winds blow onshore but less common in western Hudson Bay where offshore winds prevail (Table 4-1) (see also Markham 1988). It lifts to form low cloud as the wind strengthens. During August the Belchers are cloud-covered over 80% of the time (EAG 1984).

Summer surface winds are generally the lightest of the year and can be quite variable in direction (Figure 4-8). Onshore winds can lower coastal land temperatures drastically, while offshore winds are generally warming (see also Wilson 1976; Lafléur et al. 1987; Rouse et al. 1987, 1989; Silis et al. 1989). On the Hudson Bay Lowlands, this cooling effect extends well inland during periods of onshore winds (Figure 4-9). Most summer precipitation is in the form of rain, but snow may fall at almost any time of the summer in northern Hudson Bay. July and August snowfalls are rare in the region's other coastal communities. Monthly rainfall ranges from 25 to 100 mm and generally is greatest in the south. Thunderstorms occur at Moosonee 3-4 times per month in summer, but are markedly less frequent to the north and to the east where the colder waters exert a stabilizing influence on the air masses. Most summer storms pass from west to east across central Hudson Bay.

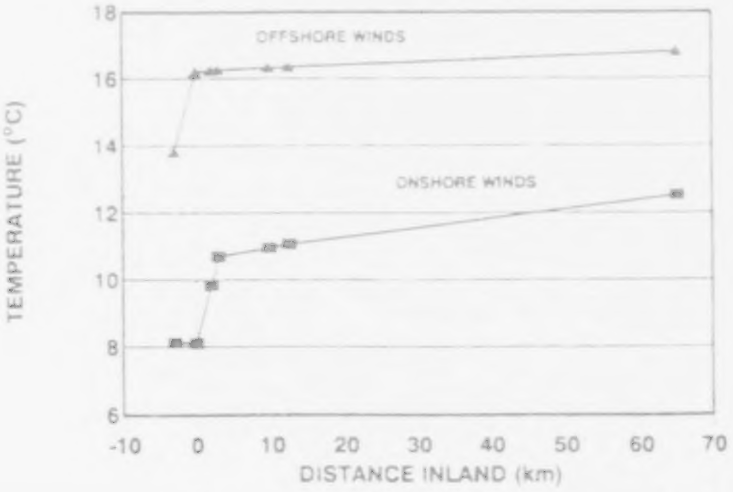

Figure 4-9. Air temperature from the intertidal zone, near Churchill, inland for onshore and offshore winds (from Rouse 1991, p. 28).

4.3 FRESHWATER INPUT CYCLE

The surface waters of the Hudson Bay marine ecosystem receive unusually large volumes of freshwater in the spring in the form of runoff and from melting sea ice. Their catchment basin for runoff is 3.1 x 10^6 km^2, larger than those of the St. Lawrence and Mackenzie rivers combined, with double the combined average annual discharge rate (i.e., 20,700 $m^3 \cdot s^{-1}$; Prinsenberg 1988b). These large runoff volumes have a strong influence on the timing and pattern of the breakup of ice cover, the surface circulation, water column stability, species distributions, and biological productivity. Ice cover does not make a net contribution of fresh water over a one-year period but, on a weekly basis, it contributes as much or more than runoff.

The annual cycle of freshwater inputs can be determined from monthly calculations of runoff plus precipitation less evaporation (R+P-E) (Figure 4-10). Each year a 64 cm layer of freshwater is added to the entire surface of Hudson/James Bay, mostly during the spring and summer months (Prinsenberg 1977, 1980, 1986a). On average, a 10.0 cm layer of water is added to the area monthly from May to October, while only a 0.5 cm layer is added monthly from November to April. Taken alone, James Bay receives a 473 cm layer of freshwater annually over its entire surface (Prinsenberg 1984, 1986a). It receives much more fresh water by precipitation than it loses by evaporation, and more runoff. James Bay's average net monthly gain of freshwater is a layer of 61 cm during the summer months, and 19 cm during the winter months.

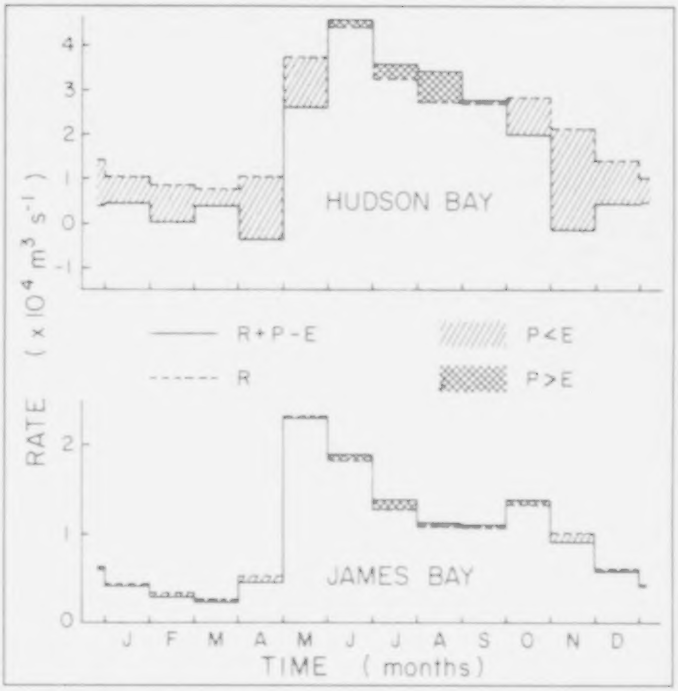

Figure 4-10. **Monthly rates of freshwater input to Hudson Bay and James Bay from runoff (R), precipitation (P), and evaporation (E) (adapted from Prinsenberg 1986a).**

River runoff is low during the winter, peaks in spring, remains constant over the summer, and decreases slowly during autumn (Prinsenberg 1977, 1980, 1988b, 1991; Figure 4-11). Major processes associated with the spring breakup of small subarctic rivers entering Hudson Bay and James Bay include the snowmelt, impoundment of meltwater by snow dams, the disintegration and ablation of ice cover, the formation and destruction of ice jams, and an exchange of flow between the river channels and their adjacent wetlands (Woo and Heron 1987). Ice jams play a greater role in the breakup of larger rivers; snow a greater role in the breakup of small Arctic rivers. In the Churchill area, snowmelt occurs about three weeks earlier on the exposed tundra than in the woodlands (Scott et al. 1993). Wetland drainages generally have little stream discharge under ice conditions in winter, peak discharge at snowmelt, and a secondary peak during autumn rains (Winter and Woo 1990). They delay runoff from rainfall but not from snowmelt, partly because the presence of frost hinders infiltration (Roulet and Woo 1986a+b).

While the James Bay marine region has only 25% of the freshwater drainage area of Hudson/James Bay, it receives over 50% of the total runoff (Prinsenberg 1980). James Bay, excluding southeastern Hudson Bay, has only 9% of the Hudson/James Bay surface area and 1.5% of the volume, yet it receives 44.6% of the runoff--its oceanographic and ice conditions are, therefore, very dependant upon runoff. Peak spring runoff flows are more

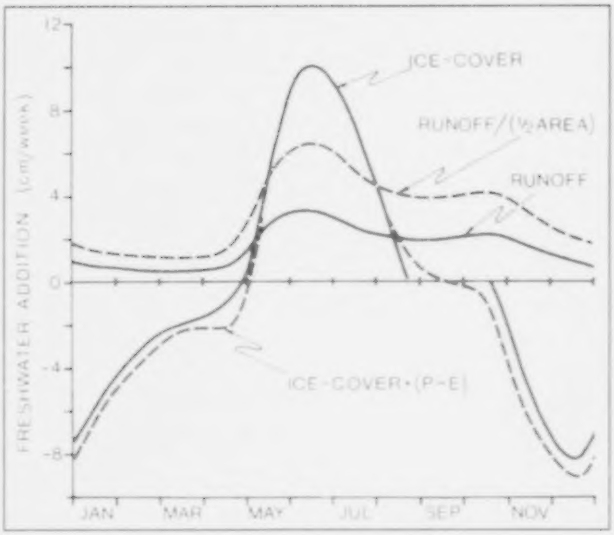

Figure 4-11. **Freshwater addition by ice cover, runoff (R), precipitation (P), and evaporation (E) for Hudson Bay, using a 1.6 m maximum ice-cover thickness (adapted from Prinsenberg 1988b).**

abrupt in James Bay than in Hudson Bay. Hydroelectric developments may not be altering the overall runoff, but they are changing its timing and spatial distribution.

Precipitation increases from winter to summer and from north to south (Table 4-1) (Prinsenberg 1977, 1980). Warm air in the south can carry more moisture than the colder air to the north and when it is cooled by the cold water surface produces more precipitation. Most of the fresh water that is lost by evaporation shows up as the large runoff per unit drainage area of rivers on the eastern coast.

Evaporation over Hudson Bay decreases from west to east as eastward-moving air picks up moisture and cools, and from south to north since the cooler northern air holds less moisture (Prinsenberg 1977, 1980). Hudson Bay loses more water on a yearly basis through evaporation to the atmosphere than it gains from precipitation. Evaporation over James Bay decreases from north to south as the wind strength decreases, even though the vapour pressure increases slightly. The evaporative losses from James Bay are offset by precipitation which is nearly double that of Hudson Bay. The evaporative cycle exhibits two peaks, one in the spring when the air temperature increases due to solar radiation, and one in autumn when the air is heated by the water itself.

Seasonal ice cover is the other large contributor to this region's freshwater budget (Prinsenberg 1988b; 1991). When the sea ice forms in the fall it sequesters fresh water and rejects salt, and when it melts in the spring it releases a layer of freshwater at the surface. The maximum thickness of ice averaged over Hudson Bay and James Bay is 160 cm, which represents a 140 cm layer of fresh water when sublimation is accounted for (20 cm, Danielson 1969). The freshwater budgets suggest that ice contributes 66% more fresh water to Hudson Bay and 40% more to James Bay than can be accounted for by the ice thickness data. Some of this water, 25 cm in Hudson Bay, is contributed by the melting of ice accumulated in thick ice ridges (Prinsenberg 1988b). Ice formation has a greater effect on the surface waters of Hudson Bay than on those of James Bay. It adds almost twice as much freshwater annually to the surface of Hudson-James Bay as is added annually by runoff and precipitation combined. In James Bay alone, however, the addition of freshwater by ice melt is small relative to the amount of freshwater added annually by runoff and precipitation.

The volume of runoff that enters Hudson Bay each summer affects salinity on the Newfoundland Shelf. There is a significant negative correlation between the interannual variation of summer runoff into Hudson Bay and salinity anomalies on the Newfoundland Shelf, with a time lag of 9 months (Myers, et al. 1990). This linkage may be important if the volume of runoff entering Hudson Bay in summer changes significantly over the long term. Ice melt in the Bay was not similarly correlated with salinity on the Shelf.

4.4 HEAT BUDGET

The surface heat flux, advection by ice, circulation, runoff, and seasonal ice cover all contribute to the heat budgets of Hudson and James bays (Danielson 1969; Prinsenberg 1984; Prinsenberg and Danard 1985). Between May and August, the incoming surface heat flux is the main contributor to these heat budgets and is balanced by the heat required to melt the seasonal ice cover and warm the water column—mainly above the pycnocline, to observed summer values (Table 4-2). The temperature difference between air and water, which determines the stability and degree of vertical convection of the air, is the most important factor determining air-sea heat fluxes (Prinsenberg and Danard 1985). In the spring, the colder water stabilizes the air and depresses vertical convection. This reduces wind stress and evaporation and increases the heat fluxes into the water. In fall, the opposite occurs. In Hudson Bay, the contributions of runoff and circulation to the heat budget are an order of magnitude smaller than the surface heat flux; in James Bay, the relative contributions of runoff and circulation to the heat budget are much greater. This strong coupling between the atmospheric environment, seasonal ice cover, and oceanographic conditions is important as it means that changes to one will affect the others (see also Cohen et al. 1994).

Table 4-2. **Heat budget results of Hudson Bay and James Bay for an observation period from 1 May to the end of August (from Prinsenberg 1984).**

	James Bay (x 10^{18} J)	Hudson Bay (x 10^{20} J)
Winter heat content	-0.1	1.2
Surface heat flux	107.0	11.7
Heat due to runoff	9.2	0.2
Ice and snow cover	-38.4	-5.0
Heat of ice transport	-4.2	~0
Advection of heat in	14.6	0.2
Advection of heat out	-35.4	-0.6
Balance	52.7	7.7
Summer heat content	48.5	7.6
Difference	4.2	0.1

4.5 TERRESTRIAL ECOZONES

While the Hudson Bay marine ecosystem is essentially Arctic, its coastlines, which extend over fourteen latitudinal degrees, exhibits a strong north-south climatic gradient. This gradient is reflected in the coastal vegetation, which changes from boreal forest in the south to tundra in the north (Hare 1950; Ducruc et al. 1976; Martini 1986b; EWG 1989; ESWG 1995; Marshall and Schut 1999). It is also reflected in the permafrost and the organic cover.

Four Terrestrial Ecozones are represented around the coasts of Hudson Bay and James Bay: 1) Hudson Plains, 2) Taiga Shield, 3) Southern Arctic, and 4) Northern Arctic (ESWG 1995; Marshall and Schut 1999) (Figure 4-12). These regions are not delineated based on climatic data, rather on their responses to climate as expressed by vegetation and reflected in soils, wildlife, and water. Moving from south (Hudson Plains) to north (Northern Arctic) trends are apparent in the vegetation, which changes from boreal forest to tundra; the soil, which becomes increasingly cryolosic; and the wildlife (see Chapters 9 and 10), which become better adapted to cold and often undertake extensive seasonal migrations. The southward deflection of these broad east-west Ecozones in the Hudson Bay-James Bay area emphasizes the magnitude of the climatic effect of the extreme southerly penetration of Arctic waters in this marine ecosystem.

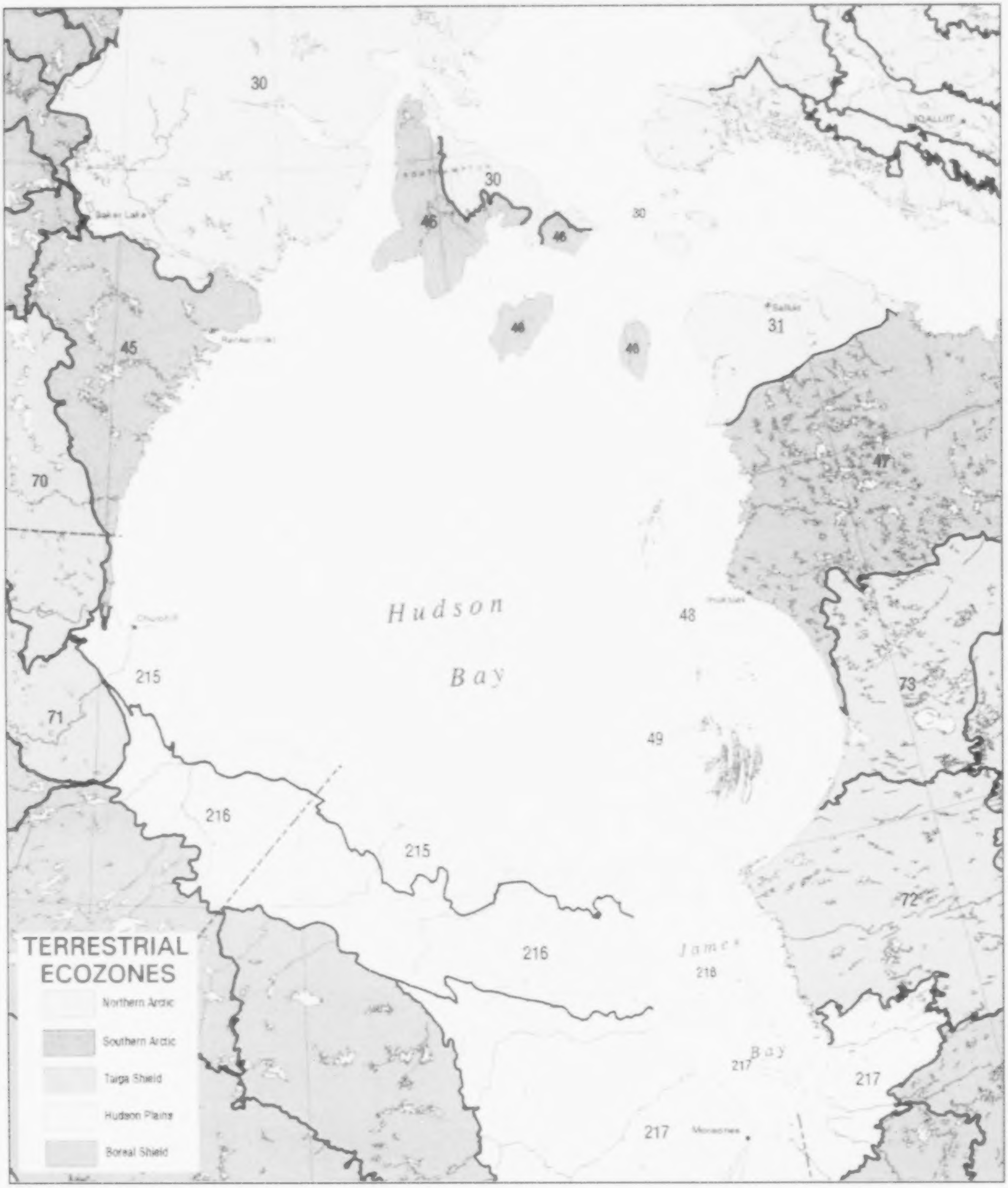

Figure 4-12. Terrestrial ecozones and ecoregions bordering Hudson Bay and James Bay (from ESWG 1995). Numbers refer to ecoregion descriptions in Table 4-3.

Table 4-3. **Features of ecoregions bordering Hudson Bay and James Bay (Sources: Marshall and Schutt 1999; NAC 1974 *et seq.*; NLUIS maps; or as cited).**

ECOZONE:	NORTHERN ARCTIC		SOUTHERN ARCTIC
Ecoregion:	**30 Wager Plateau**	**31 Northern Ungava Peninsula**	**45 Maguse River Upland**
TERRAIN	Archean rocks of the Canadian Shield form broad, sloping uplands, plains and valleys; lichen covered rock outcroppings are prominent. Elevation rises gradually westward from Chesterfield Inlet to 600 m asl.	Folded Archean granite and granitic gneiss bedrock of the Canadian Shield forms a series of east-west ridges and valleys with a relatively high relief in the west; more subdued relief in the east where hills merge with plateaux. The undulating surface rises from 100 m asl near Hudson Bay to 675 m asl in the northeast. Raised beaches occur along the coast. Postglacial limits of marine innundation are 120-167 m asl. The Hudson Bay coastline is complex north to near Ivujivik.	Archean rocks of the Canadian Shield form broad, sloping uplands and lowlands. Hummocky bedrock outcrops covered with discontinuous acidic, sandy, granitic tills are dominant. Prominent eskers. Elevations rise gradually from the coast to 330 m asl in the north and west; relief and elevation increase moving inland and northward. Postglacial marine limits 127-187 m asl. Low-lying marshy coast with little coastal development, few islands or shoals, and wide tidal flats south of Arviat; complex rocky coast north to Rankin Inlet; cliff and headland coast further north.
ECOCLIMATIC REGION	**LOW ARCTIC**	**LOW ARCTIC**	**LOW ARCTIC**
Mean temperatures	Annual -11°C, summer 4.5°C, winter -26.5°C	Annual -8.5°C, summer 3°C, winter -20°C	Annual -11°C (north) to -8°C (south), summer 6°C, winter -24°C
Mean annual precipitation	200-300 mm	200-300 mm	250-400 mm; >400 mm south of Arviat
PERMAFROST	Continuous, low ice content.	Continuous, low ice content.	Continuous, medium ice content.
SURFACE MATERIALS (Figure 3-11)	Mainly bedrock outcrops near the coast, with increasing cover of glacial tills, drumlins, eskers, and organics inland.	Mainly unconsolidated materials (glacial tills, glaciomarine deposits, and organics) near the southwest coast; bedrock is increasingly exposed moving northeast. Some frost-shattered bedrock cover in the Povungnituk Hills.	Unconsolidated glacial tills, glaciomarine deposits, and organics; scattered bedrock outcrops inland. Many drumlins and eskers.
WETLANDS (NAC 1986)	Well drained, <5%.	Well drained, <5%.	Wetlands, mostly lowland low- and high-centred polygon fens, cover 26-50% of the ecoregion.
DOMINANT SOILS	Turbic and Static Cryosols developed on discontinuous, thin, sandy moraine and alluvial deposits; large areas of Regosolic Static Cryosols are associated with marine deposits along the coast.	Turbic Cryosols developed on loamy marine sediments along the coast and on thin, discontinuous glacial drift deposits inland; rock outcrops and inclusions of Organic Cryosols are also present.	Turbic Cryosols dominate but unfrozen Organic (Mesisol) and Regosolic soils also occur.
VEGETATION (FORMATION TYPE: Physiognomy: characteristic and dominant species)	TUNDRA: discontinuous cover of Arctic stoney lichen-heath: lichens, Labrador tea, Arctic bell and heather north of Wager Bay with Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, Dryas spp., and Vaccinium spp. to the south. Taller birch, willow, and alder occur on warm sites; willow and sedge dominate wet sites. Frost free period 20-65 days.	TUNDRA: nearly continuous cover of Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, *Dryas* spp., and *Vaccinium* spp. along the northern coast and *Arctic stoney lichen-heath*: lichens, Labrador tea, Arctic bell, and heather elsewhere. Taller birch, willow, and alder occur on warm sites; willow and sedge dominate wet sites. Frost free period 20-40 days.	TUNDRA: cover of Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, *Dryas* spp., and *Vaccinium* spp. Taller birch, willow, and alder occur on warm sites; wet sites are dominated by willow, sphagnum moss, and sedge. Frost free period 60-80 days.
SETTLEMENTS (change in population from 1996 to 2001)	Repulse Bay (559 to 612); Baker Lake (1305 to 1507).	Ivujivik (274 to 298); Salluit (929 to 1072).	Arviat (1559 to 1899); Chesterfield Inlet (337 to 345); Rankin Inlet (2058 to 2177).

Dominant soils (see also http://sis.agr.gc.ca/cansis/nsdb/slc/webmap.html**); Settlements (see** http://www12.statcan.ca **)**

Table 4-3 Continued.

ECOZONE:	**SOUTHERN ARCTIC**		
Ecoregion:	**46 Southampton Island Plain**	**47 Central Ungava Peninsula**	**48 Ottawa Islands**
TERRAIN	Low-lying coastal plain underlain by flat-lying Palaeozoic carbonate rocks. Bedrock outcrops are common. Little relief; elevation generally < 90 m but rising inland to 200 m asl. Postglacial limits of marine innundation 150-175 m asl. Low-lying sometimes marshy coast often with tidal flats, little coastal development, and few islands.	The undulating surface is situated on Archean granites and gneisses of the Canadian Shield. Elevation mostly > 200 m asl but can reach about 500 m asl; coastal islands mostly <100 m asl. Bare rock outcrops are common; small lakes cover about 20% of the area. Region drains east into Ungava Bay, via the aux Feuilles and Arnaud rivers, and west into Hudson Bay via the Povungnituk and Kogaluc rivers. Postglacial limits of marine innundation along the Hudson Bay coast are 105-242 m asl--highest in the south. Bold, rugged coastline. Cliff and headland coast north to the Hopwell Islands and near Cape Smith; complex coastline in-between.	Situated on Proterozoic rock of the Canadian Shield. Bedrock outcrops are common. Gilmour Island is the highest, rising abruptly to 340 m asl. Post-glacial limits of marine innundation 158 m asl.
ECOCLIMATIC REGION	LOW ARCTIC	LOW ARCTIC	LOW ARCTIC
Mean temperatures	Annual -11°C, summer 3°C, winter -24.5°C	Annual -7°C, summer 3.5°C, winter -17.5°C	Annual -9°C, summer 3°C, winter -20°C
Mean annual precipitation	200-300 mm	400-500 mm	About 300 mm
PERMAFROST	Continuous, medium ice content composed of ice wedges.	Continuous, low ice content.	Extensive discontinuous.
SURFACE MATERIALS (Figure 3-11)	Glaciomarine deposits and organics in the west and southeast; glacial till on uplands northeast of Cape Low; many drumlins.	Unconsolidated glaciomarine deposits along the Hudson Bay coast south to near the Hudson Bay Arc; bedrock exposed or covered with glacial tills, glaciolacustrine deposits, and/or organics to the south and inland. Drumlins and eskers are common inland.	Bedrock with some organic cover.
WETLANDS (NAC 1986)	26-50% wetlands in the southwest (Boas River-Cape Kendal area), 6-25% west of Hansine Lake, <5% elsewhere.	Well drained, <5%.	Well drained, <5%.
DOMINANT SOILS	Static and Turbic Cryosols developed on level to undulating morainal and marine deposits.	Turbic Cryosols with inclusions of Organic Cryosols.	Turbic and Static Cryosols developed on level to undulating morainal and marine deposits.
VEGETATION (FORMATION TYPE: Physiognomy: characteristic and dominant species)	TUNDRA: nearly continuous cover of Arctic stoney lichen-heath: lichens, Labrador tea, Arctic bell, and heather north of Hansine Lake and on Bell Peninsula with Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, Dryas spp., and Vaccinium spp. elsewhere. Wet sites are dominated by willow, sedge, and moss. Frost free period 30-60 days.	TUNDRA: nearly continuous cover of Arctic stoney lichen-heath: lichens, Labrador tea, Arctic bell, and heather along the northeast coast; with Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, *Dryas* spp., and *Vaccinium* spp. elsewhere except along the southern border, where there is TUNDRA-OPEN WOODLAND: lichen-heath-shrubs-patches of needle bearing trees: lichen and black spruce. Wet sites are dominated by willow, sedge, and moss. The southern portion of the region has a mix of tundra vegetation and open, dwarf coniferous forest. Frost free period 60-80 days.	TUNDRA: Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, *Dryas* sp. and *Vaccinium* spp. Wet sites are dominated by willow and sedge. Frost free period 60-80 days.
SETTLEMENTS (change in population from 1996 to 2001)	Coral Harbour (669 to 712).	Inukjuak (1184 to 1294); Povungnituk (1169 to 1287); Aupaluk (159 to 159).	

Table 4-3 Continued.

SOUTHERN ARCTIC	TAIGA SHIELD	
49 Belcher Islands	**70 Kazan River Upland**	**72 La Grande Hills**
Situated on elaborately folded Proterozoic sedimentary and volcanic rocks. Less than 100 m asl except on northeastern Flaherty I. (122 m asl) and Tukarak I. (182 m asl). Relief generally low. Coastline rocky. The island group was covered by the sea following the last glaciation.	Crystalline, massive Archean rocks of the Canadian Shield form broad, sloping uplands and lowlands. Ridged to hummocky bedrock outcrops covered with discontinuous acidic, sandy, granitic till are characteristic. Prominent eskers and small to medium-sized lakes are common. Relief is low and elevations rise form about 100 m near the Hudson Bay coast, to 300-400 m asl in the west. Postglacial limits of marine inundation 152-180 m asl.	Mostly Archean Shield bedrock overlain by morainal deposits. Rises inland to 450 m asl. Varied, mostly low lying (<100 m asl), coast: CONN R. TO PAUL BAY: rocky glaciomarine plain. Relief increases to the north from undulating to rolling. Irregular shoreline with many islands. Wide tidal flats often fringed in bays by wide salt marshes. CACACHISCHOUANE PT. TO PT. LOUIS XIV: irregular bedrock unevenly covered by thin marine and coastal deposits. Very complex shoreline with many low islands. Tidal flats in most bays, narrow marshes only in larger bays. Sand and boulder beaches. Low rocky hills and drumlins are major relief (Dionne 1980a). PT. LOUIS XIV TO KUUJJUARAPIK: mainly rocky hills or plains, some raised beaches; land rises northward to 250 m near Kuujjuarapik. Relief increases with elevation from undulating to rolling. Post-glacial limits of marine innundation: 200-270 m asl, lowest in the south.
HIGH SUBARCTIC	**HIGH SUBARCTIC**	**LOW SUBARCTIC**
Annual -5.5°C, summer 5.5°C, winter -18.5°C	Annual -8°C, summer 8°C, winter -24.5°C	Annual -4°C, summer 8.5°C, winter -16.5°C
About 500 mm	>200 mm (north) to >400 mm (south)	<600 mm along Hudson Bay to 800 mm in the southeast
Extensive discontinuous, low to no ice content.	Nearly continuous, low to medium ice content. Grades to extensive discontinuous permafrost at southern margins. Ice wedges are sparse throughout.	Limited to isolated patches, mainly in wetlands, with little or no ice content.
Bedrock with some organic cover.	Unconsolidated glacial tills, glaciomarine deposits, and organics; scattered bedrock outcrops inland. Many drumlins and eskers.	Unconsolidated glaciomarine deposits and organics along the coast, with some bedrock outcrops along the Hudson Bay Arc; increasing bedrock exposure and glacial till cover moving inland.
Well drained, <5%	6-25% wetland cover, drainage improves moving northwest from the coast.	51-75% in the southwest near James Bay, decreasing to 6-25% inland to the northeast.
Dominantly rockland with Crysols, and some Brunisols in well-drained coarse-textured substrates.	Dystric Brunisols on sandy eskers dominate; Turbic Cryosols in permanently frozen sites; Organic Cryosols on wetlands. Patterned ground is widespread, and mineral soils exhibit discontinuous or distorted soil horizon development.	Dystric Brunisols with significant inclusions of Humo-Ferric Podzols and Organic (Mesisol and Fibrisol) soils. Regisols and rockland near much of the coastline. Active layer of 40 cm at Kuujjuarapik (see also Vincent et al. 1987).
TUNDRA: Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, *Dryas* sp. and *Vaccinium* spp.. Frost free period 60-80 days.	Transitional between tundra and open woodland: TUNDRA: Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, Dryas spp., and Vaccinium spp. in the northeast; TUNDRA-OPEN WOODLAND: lichen-heath-shrubs-patches of needle bearing trees: lichen and black spruce in the middle; OPEN WOODLAND: Lichen floor with scattered needle leaf trees: lichen, spruce, and tamarack in the southwest. Very stunted stands of black spruce and tamarack with secondary quantities of white spruce, a shrub layer of dwarf birch, willow, and ericaceous shrubs, and ground cover of cottongrass, lichen, and moss predominate. Drier sites dominated by open stands of white spruce, ericaceous shrubs, and ground cover of mosses and lichens; wet sites by tussocks of sedge, cottongrass, and sphagnum moss. Low shrub tundra is common. Frost free period 60-80 days.	Transitional area between tundra in the north and boreal forest in the south. TUNDRA: Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, *Dryas* sp., *Vaccinium* spp., and Labrador tea on the islands and along the coast north of Roggan River. OPEN WOODLAND: Lichen floor with scattered needleleaf trees: lichens, spruce and tamarack along the coast from Paul Bay north to Roggan River and inland to the south and east. BOREAL FOREST: Needleleaf trees: spruce and balsam fir along the James Bay coast south of Paul Bay flanked by BOGS-ORGANIC TERRAIN: Small lakes-moss and sedge covered floor and strings of needleleaf trees: sphagnum moss, sedges, black spruce, tamarack. Frost free period 70-90 days.
Sanikiluaq (631 to 684)		Chisasibi (3251 to 3467) Kuujjuarapik (579 to 555)

Table 4-3 Continued.

ECOZONE:	**TAIGA SHIELD**	**HUDSON PLAINS**
Ecoregion:	**73 Southern Ungava Peninsula**	**215 Coastal Hudson Bay Lowland**
TERRAIN	This ecoregion includes the south-central section of Larch Plateau and the Richmond Hills. Larch Plateau has a hummocky to undulating surface with elevations that reach ~ 500 m asl. Inland, elevations typically 100-300 m asl, local relief is seldom >30 m. The Richmond Hills are highlands in the west, where mainly east-facing cuestas of Proterozoic sedimentary and volcanic rocks dip steeply into Hudson Bay. The rugged cliff and headland coast rises from 250 m near Kuujjuarapik to 450 m asl west of Richmond Gulf; coastal islands are generally <100 m asl. Runoff flows east into Ungava Bay, via the Du Gue and Melezes rivers and Riviere aux Feuilles, and west into Hudson Bay via Petite riviere de la Baleine. Small, generally shallow lakes cover ~20% of the area. Post-glacial limits of marine innundation, 225 m asl east of Richmond Gulf rising to 315 m asl east of Manitouk Sound. The Sakami End Moraine occurs in the Kuujjuarapik area. There are well-developed raised marine beaches in the Richmond Gulf area.	Low-lying, marshy coastal plain with extensive tidal flats, developed on flat-lying Palaeozoic limestone bedrock. Rises to ~120 m asl in the south; very little local relief or coastal development; few small coastal islands or shoals. Large estuaries at the outlets of the Churchill and Nelson rivers. Post-glacial limits of marine innundation are 120-180 m asl. Along the coast east of the Nelson River numerous, parallel, well-drained raised beaches present a striking pattern of successive white spruce-covered ridges, alternating with fens, polygonal peat plateaus, and peat plateaus. North of the Nelson River beaches are more subdued and the terrain is dominated by fens, polygonal peat plateaus, and peat plateaus. Peat plateaus occur often in parallel rows marking the underlying beaches. In the fens, small incipient palsa bogs are common. The coastal areas are dominated by marshes and shallow waters and extensive tidal flats, especially north of the Nelson River.
ECOCLIMATIC REGION	**MID-HIGH SUBARCTIC**	**HIGH SUBARCTIC**
Mean temperatures	Annual -6°C, summer 6°C, winter -18°C.	Annual -4°C but lower -4°C in Manitoba, summer 10.5°C, winter -19°C.
Mean annual precipitation	475-650 mm (north-south).	400 mm in the northwest to 600 mm in the east.
PERMAFROST	Extensive and discontinuous with low to medium ice content in the northern two-thirds, and sporadic discontinuous elsewhere.	Permafrost with low to high ice content is widespread. Ekwan Point is the southernmost extension of continuous permafrost in the Hudson Bay Lowland (Rouse and Bello
SURFACE MATERIALS (Figure 3-11)	Extensive bedrock outcrops along the coast and in the north, covered by organics and by glaciomarine deposits near the coast and glacial tills inland.	Unconsolidated coarse and fine-grained glaciomarine deposits mostly beneath organics (peat bogs); some alluvial deposits along the Manitoba coast; few, if any, bedrock outcrops.
WETLANDS (NAC 1986)	Well-drained, <5%	Poorly drained, >75%
DOMINANT SOILS	Turbic Cryosolic and Dystric Brunisolic soils with significant inclusions of Humo-Ferric Podzols, Organic Cryosols. Regosols and rockland near the coast.	Organic Cryosols formed on sedge and fibrous sphagnum peat are dominant; Mesisols formed on moderately decomposed sedge and woody peat are significant; and saline Regosols and Gleysols occur on silty to clayey marine sediments along the coast. (see also Canada Soil Inventory 1989).
VEGETATION (FORMATION TYPE Physiognomy: characteristic and dominant species)	TUNDRA: Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, Labrador tea, crowberry, *Dryas* spp., and *Vaccinium* spp. in a narrow band along the coast and north of Richmond Gulf. TUNDRA-OPEN WOODLAND: Lichen-heath-shrubs-patches of needle bearing trees: lichen and black spruce from Richmond Gulf south and in the east. Poorly drained sites often support tussocks of sedge, cottongrass, and sphagnum moss. The ecoregion's northern boundary is where the limit of trees is reached in Quebec. Frost free period 60-80 d.	TUNDRA: Arctic dwarf shrubs-sedges-lichen-heath: dwarf birch and willow, sedges, *Dryas* sp., *Vaccinium* spp., and Labrador tea near the coast. BOGS-ORGANIC TERRAIN: Small lakes-moss and sedge covered floor and strings of needleleaf trees: sphagnum moss, sedges, black spruce and tamarack inland. The vegetation is characterized by very open stands of stunted black spruce and tamarack with secondary quantities of white spruce; a shrub layer of dwarf birch, willow or ericaceous shrubs; and ground cover of cottongrass or lichen and moss. Poorly drained sites usually support tussock vegetation of sedge, cottongrass, and sphagnum moss. Low shrub tundra vegetation consisting of dwarf birch and willow is also common. Frost free period 60-80 days.
SETTLEMENTS (change in population from 1996 to 2001)	Umiujuaq (315 to 348).	Churchill (1089 to 963). Fort Severn (362 to 401). Peawanuck (239 to 193).

Table 4-3 Continued.

HUDSON PLAINS	
216 Hudson Bay Lowland	**217 James Bay Lowland**
Low-lying, marshy coastal plain with extensive tidal flats, developed on flat-lying Palaeozoic limestone bedrock. Rises to about 120 m asl in the south; very little local relief; slopes of coastal marshes often <2 m per km. Little coastal development; few small coastal islands or shoals. Post-glacial limits of marine innundation, 150-180 m asl.	Low-lying, flat to undulating marshy clay coastal plain with a few rocky hills and drumlin ridges forming points and islands. Underlain by flat-lying, Palaeozoic limestone bedrock that slopes gently towards James Bay. Nearshore zone shallow with few islands and shoals. Coastline of large open bays; sandy and muddy tidal flats up to 2 km wide are common (some with boulders), often fringed on the landward side by wide tidal marshes. Elevation <100 m with very little local relief; slopes of coastal marshes often <2 m per km. Post-glacial limits of marine innundation, 137-270 m asl, lowest in the southwest. Hurricanaw Interlobate Moraine in the Rupert Bay area and on islands northward to North Twin Island.
LOW SUBARCTIC	PERHUMID HIGH BOREAL
Annual -3.5°C but can be -5°C in Manitoba, summer 11°C, winter -18.5°C	Annual -2°C, summer 11.5°C, winter -16°C
<500 mm in the west to<700 mm near James Bay	700-800 mm
Moderate to high ice content permafrost is widespread, especially in organic deposits and along the northern boundary.	Sporadic and discontinuous with medium to high ice content north and west of Kashechewan, isolated patches elsewhere.
Unconsolidated coarse and fine-grained glaciomarine deposits, mostly beneath organics (peat bogs), near James Bay; more glaciolacustrine deposits, glacial till, and organic deposits to the west; few, if any, bedrock outcrops.	Unconsolidated coarse and fine-grained glaciomarine deposits, mostly beneath organics (peat bogs), and organic deposits near James Bay; glacial till and organic deposits inlandt; drumlins common, few bedrock outcrops.
Wetlands, mainly peat plateau and palsa bogs and horizontal fens cover >75% of the mainland and 51-75% of Akimiski and the Twin islands.	Wetlands, mainly northern ribbed fens, northern plateau bogs, and palsa bogs cover from 50% of the area in the south to >75% in the north, around James Bay, and on Charlton I.
Organic Cryosols, Mesisols, and Fibrisols are the dominant soils developed on organic materials. Eutric Brunisols are associated with marine and till upland deposits (see also Protz 1982b).	Organic Mesisols and Fibrisols with some Organic Cryosols. Limited areas of Dystric and Eutric Brunisols on upland sands. Eutric Brunisols and Gleysols are associated with river levees; clayey uplands may have Gray Luvisol soils. Gleysols are characteristic of the marshes and Regesols to Podzols of sand and gravel beach ridges (see also Protz 1982b).
TUNDRA: Arctic dwarf shrubs-sedges-lichen-heath: shrubby birch and willows, sedges, blueberry, crowberry, and Labrador tea near the coast north of Ekwan Point and on Akiminski Island and the Twin islands. BOGS-ORGANIC TERRAIN: Small lakes-moss and sedge covered floor and strings of needleleaf trees: sphagnum moss, sedges, black spruce and tamarack elsewhere. Open stands of stunted black spruce, tamarack and white spruce dominate, with a shrub layer of dwarf birch, willow and northern Labrador tea, and ground cover of cottongrass or moss and lichen. Dry sites often support open stands of white spruce with an ericaceous shrub layer and ground cover of lichen; wet sites sedge and cottongrass tussocks or sphagnum hummocks. Balsam, poplar, white spruce and paper birch are common along rivers. Frost free period 75-100 days.	TUNDRA: Arctic dwarf shrubs-sedges-lichen-heath: shrubby birch and willows, sedges, blueberry, crowberry, and Labrador tea on Charlton Island. BOGS-ORGANIC TERRAIN: Small lakes, moss and sedge covered floor and strings of needleleaf trees: sphagnum moss, sedges, black spruce, and tamarack elsewhere except in the south where there is BOREAL FOREST: needleleaf trees: spruce, jack pine, tamarack. Most of the ecoregion is poorly drained, and the dominant vegetation consists of sedge, mosses, and lichens with or without stunted black spruce and tamarack. Frost free period 75-100 days.
Shamattawa (749 to 897).	Attawapiskat (1253 to 1293); Waskaganish (1548 to 1699); Moosonee (1939 to 936); Eastmain (1978 to 1422).

4.6 SUMMARY

The Hudson Bay marine ecosystem is abnormally cold relative to other areas at the same latitude, and extends through five ecoclimatic regions from humid high boreal in the south to low Arctic in the north. Its climate differs from north to south and east to west. The winters are long and cold; the summers are cool. The harshest climate is found in northwestern Hudson Bay where there is the greatest influence of cold Arctic air masses. Strong winds and persistent low temperatures are characteristic of this area. While neither is as extreme as in some continental areas, in combination they make it the coldest part of Canada based on wind chill. Other areas have either moderating southern or marine influences and do not exhibit the extremes of western Hudson Bay--particularly the high wind chills and frequent blizzards.

The marine environment depends strongly on local wind stress, runoff, radiation heat flux, and annual ice cover. There is an annual net gain of 473 cm of fresh water over the entire surface of James Bay, where precipitation is much greater than evaporation and runoff is high. This is much greater than the average for Hudson/James Bay, which has an annual net gain of only 64 cm over the entire marine surface. Hudson Bay loses more fresh water through evaporation than it gains from precipitation. Runoff has a strong influence on oceanographic and ice conditions, particularly in James Bay.

There is extreme variation in the range of average temperatures and average total precipitation in time, seasonally and annually, and in space throughout the region. There is a strong average precipitation gradient across the region, from less than 200 mm per year in the northwest to over 800 mm per year in the southeast. Evidence for change in these patterns related to global warming is discussed in Section 17-1.

The marine ecosystem has a strong influence on the surrounding land area, contributing particularly to the unusual southern extent of the permafrost. This influence is demonstrated by the presence of four ecozones along the coastline, each of which reflects the response of vegetation, soils, wildlife, and water to climattic and geological factors. Moving from south (Hudson Plains) to north (Northern Arctic) trends are apparent in the vegetation, which changes from boreal forest to tundra; the soil, which becomes increasingly cryolosic; and the wildlife, which become better adapted to cold and often undertake extensive seasonal migrations. The southward deflection of these broad east-west Ecozones in the Hudson Bay-James Bay area emphasizes the magnitude of the climatic effect of the extreme southerly penetration of Arctic waters in this marine ecosystem.

5.0 OCEANOGRAPHY

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The Hudson Bay marine ecosystem consists of two oceanographically distinct marine regions (Dunbar 1988)(Figures 1-1 and 1-2). The water properties of these regions depend mainly on exchanges with Foxe Basin and Hudson Strait and the large freshwater input from both runoff and melting sea ice in the spring and summer (Ingram and Prinsenberg 1998). An understanding of their differences is critical to the design and integration of coastal zone management initiatives.

The northern area, or **Hudson Bay marine region**, is characterized by the presence of Arctic marine water and biota, complete winter ice cover and summer clearing, moderate semidiurnal tides of Atlantic origin, a strong summer pycnocline, greater mixing and productivity inshore than offshore, and low biological productivity relative to other oceans at similar latitudes. Hudson Bay lacks the typically subarctic species that are found in Hudson Strait but does support some of the relict warm-water species found in James Bay.

The southern area, or **James Bay marine region**, is closely coupled oceanographically to the Hudson Bay marine region but its waters are typically shallower and more dilute, being modified to a much greater extent by freshwater runoff from the land. Its species composition reflects these Arctic and freshwater influences and it supports a variety of warm-water species that are relicts of an earlier connection with the Atlantic and Pacific oceans. These plants and animals have disjunct distributions and are rare or absent elsewhere in Canada's Eastern Arctic waters. Southeastern Hudson Bay is included in this region with James Bay largely on the basis of biogeography (Dunbar 1988). Strong density stratification limits mixing and leads to considerable surface warming by insolation in both marine regions.

Because of its remote location and the noncommercial nature of its marine resources, relatively few oceanographic field programs have been undertaken in this area (Martini 1986a; Ingram and Prinsenberg 1998). Seasonal ice cover effectively prevents most year-round research and the shallow coastal waters make it very difficult to conduct bay-wide research from a single research platform. Consequently, characteristics of the circulation and water mass are not well known, especially outside the open water period.

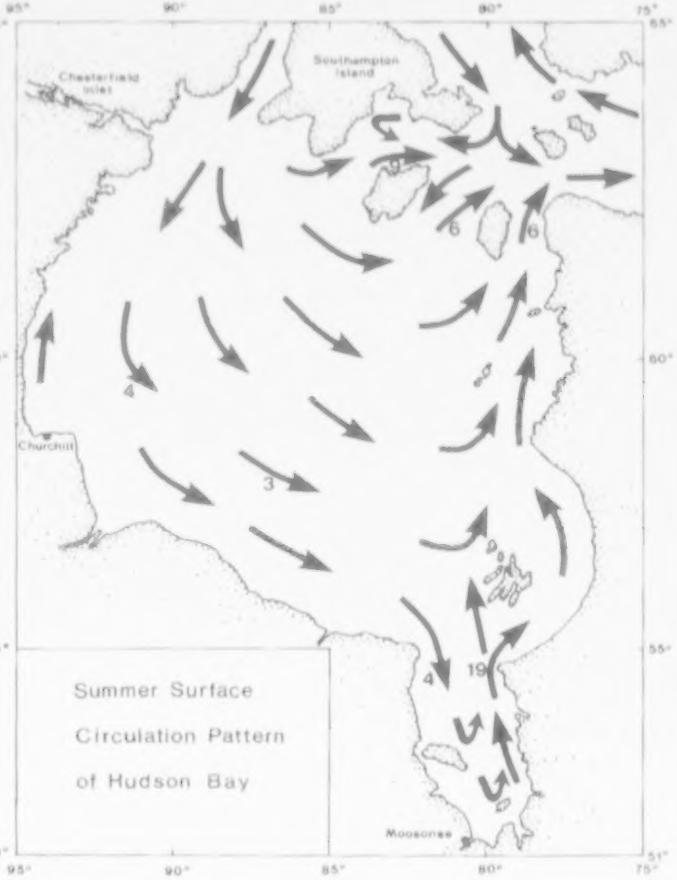


Figure 5-1. General surface layer circulation pattern for the summer condition of Hudson Bay and James Bay. Numbers are observed velocity values in cm•s^{-1} (from Prinsenberg 1986a).

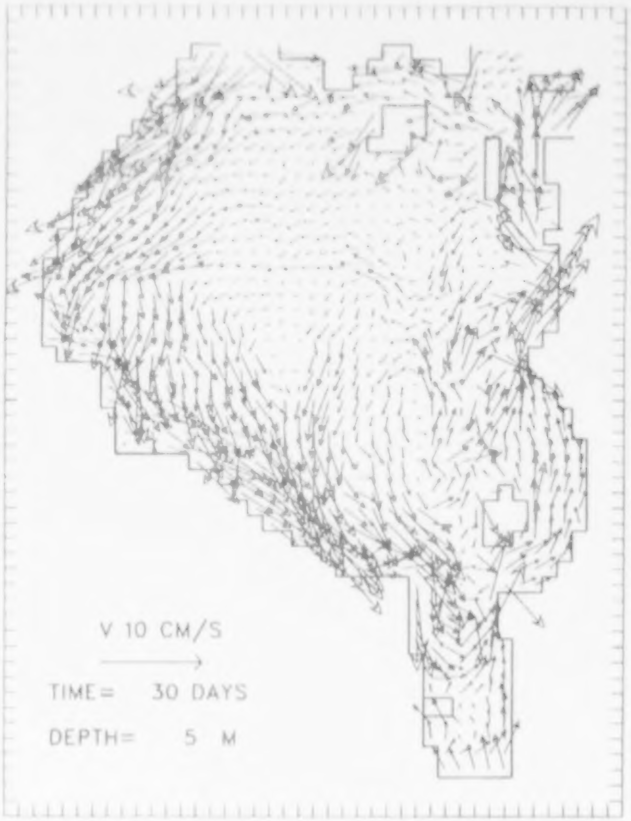


Figure 5-2. Surface circulation in Hudson Bay and James Bay determined from model results (from Ingram and Prinsenberg 1998, p. 852 as modified by J. Wang from Wang 1993).

Table 5-1. Oceanographic research expeditions to the Hudson Bay (H) and James Bay (J) marine regions, with selected references[1].

Vessel(s)	Year	Region	Selected Reference(s)
Burleigh	1914	J	Lower 1915; Melvill 1915; Comeau 1915.
Acadia	1929, 1930, 1931	H	Bell and MacFarlane 1933.
Loubyrne	1930	H, J	Davidson 1931; Hachey 1931, 1933, 1935; Huntsman 1931; Willey 1931; Vladykov 1933.
Haida	1948	H	Bailey and Hachey 1951.
Calanus	1953-1961	H, J	Dunbar 1958; Grainger and Hunter 1959; Grainger 1960, 1982; Bursa 1961; Trason 1964; Barber 1967, 1972; Squires 1967; Powell 1968; Wacasey et al. 1976; Rochet and Grainger 1988.
Lemming	1953	J	Edwards 1961.
Labrador	1955, 1956, 1959, 1967	H, J	Campbell 1958, 1959; Barber 1967.
Theta	1961	H, J	Barber 1967, 1968; Grainger 1963; Pelletier et al. 1968; Pelletier 1969, 1986.
John A. MacDonald	1962	H, J	Barber 1967, 1968.
Theron	1965	H	Pelletier et al. 1968; Hood 1969; Pelletier 1986.
Hudson	1965, 1982, 1987, 1992, 1996, 2003	H, J	Pelletier et al. 1968; Hood 1969; Pelletier 1986; Drinkwater and Jones 1987; Henderson 1989; Bilodeau et al. 1990; Josenhans and Zevenhuizen 1990; Drinkwater et al. 1991; Jones and Anderson 1994; Saucier et al. 1994; this volume Sedtion 16.
Narwhal	1972, 1973, 1974, 1975, 1988	H, J	Grainger and McSween 1976; Wacasey et al. 1976; El-Sabh and Koutitonsky 1977; Anderson 1979; Anderson and Roff 1980 a+b; Gerrath et al. 1980; Anderson et al. 1981; Prinsenberg 1976, 1977a, 1982, 1986a+b; Pett and Roff 1982; Josenhans and Zevenhuizen 1990; Josenhans et al. 1991
Petrel	1976, 1978	H, J	Budgell 1976, 1982; Brooks 1979; Legendre and Simard 1979; Pett and Roff 1982.
Techno-Richelieu	1976	J	Legendre and Simard 1978, 1979.
L'Epinoche	1979, 1980	J	Grenon 1982.
Aiviq, Rocky Point	1990	J	Morin 1991.
Baffin	1990	J	Josenhans et al. 1991.
Fogo Isle	1993	H, J	Saucier et al. 1994; Harvey et al. 1996, 2001; Simard et al. 1996; this volume Chapter 16.
Des Groseillers	2003	H	Saucier et al. 2004b.

[1] See also general works by Barber (1967) and Dunbar (1982).

Oceanographic exploration began in the Hudson Bay marine region in 1929 but did not begin in earnest in the James Bay region until 1955 (Table 5-1; Dunbar 1982; Martini 1986a). Since the 1970's, most of this research has been directed toward predicting and assessing the effects of existing and proposed large-scale hydroelectric developments. Coastal conditions downstream of affected river systems, in particular the Eastmain, La Grande, Grande Baleine, Nottaway, Broadback, and Rupert rivers in Quebec and the Churchill and Nelson rivers in Manitoba, have received most attention.

Oceanographic bibliographies have been compiled for southeastern Hudson Bay (CSSA 1991; Hydro Quebec 1991a) and James Bay (Hydro Quebec 1991b). An annotated general bibliography of research on Hudson and James bays has also been prepared for DFO (Stewart 2001). The cumulative impacts of development on Hudson and James bays have been considered at workshops organized by the Department of Fisheries and Oceans (e.g., Bunch and Reeves [ed.] 1992; Gilbert et al. 1996) and the Hudson Bay Programme (Sallenave 1994). The latter initiative by the Rawson Academy of Aquatic Sciences, CARC, and the Environmental Committee of the Municipality of Sanikiluaq also includes a broad review of human impacts on the bays (Sly 1994, 1995) and a comprehensive study of traditional ecological knowledge (McDonald et al. 1995a+b, 1997).

While the descriptions that follow use the present tense, the data on which they are based were often collected in the 1970's, before extensive hydroelectric development. Oceanographic changes effected by these developments, which are considered stressors of the Hudson Bay marine ecosystem, are discussed in Chapter 15. Extensive multi-year, multidisciplinary research on the marine ecosystem is planned over the next decade under the MERICA (étude des MERs Intérieures du Canada) and ArcticNet programs (Saucier et al. 2004b; D. Barber, U. Manitoba, Winnipeg, pers. comm.; http://www.arcticnet-ulaval.ca/).

5.1 CIRCULATION

In summer, surface water circulates cyclonically (counterclockwise) around Hudson Bay, and the deep water moves in the same general direction but is influenced by bottom topography (Figure 5-1 and Figure 5-2; Hachey 1935, 1954; Barber 1967; Prinsenberg 1986a,b; Wang et al. 1994a). Cold, saline Arctic water from Foxe Basin enters Hudson Bay in the northwest via Roes Welcome Sound (Tan and Strain 1996). As it flows eastward along the southern coast of Hudson Bay some of this water enters James Bay while the remainder is deflected northward to exit northeastward into Hudson Strait. A westward, wind-driven return flow across the top of Hudson Bay has been predicted by modelling studies (Murty and Yuen 1973; Wang et al. 1994), and there is a small--perhaps intermittent, intrusion of Atlantic water from Hudson Strait at the northeastern corner of Hudson Bay. The extreme southerly incursion of Arctic waters creates Arctic oceanographic conditions much further south than elsewhere along the North American continent, and is a key feature of the Hudson Bay marine ecosystem.

Mathematical modelling suggests that the main reasons for this stable cyclonic circulation are the relatively weak coastal currents with limited coastal development to cause mixing, a relatively strong Coriolis effect that stabilizes the flow pattern by turning the freshwater outflow from rivers cyclonically around Hudson Bay, and strong density stratification due to intense freshening in summer (Wang et al. 1994a). This circulation is maintained by inflow/outflow forcing that likely occurs year round, and reinforced during the open water season by wind and buoyancy forcing. The total basin wide volume transport is an estimated 0.55 Sv, of which 0.2 Sv is inflow/outflow induced transport, 0.23 wind-driven transport, and 0.12 Sv buoyancy-driven transport. There are narrow coastal jets along all but the northern coast that appear to driven by freshwater inputs from runoff, ice melt discharge, and precipitation that create buoyancy driven circulation.

The observed monthly mean residual currents that are independent of tides are in the range of 4 to 6 $cm \cdot s^{-1}$ (Prinsenberg 1986b; S. Prinsenberg, DFO, Dartmouth, NS, pers. comm.). They are more variable at the surface than at greater depths, and are stronger at all depths during summer than winter. Seasonal variations reflect the effects of both wind stress and density-driven components of the circulation. Winds are generally weaker and more variable in summer than they are in the fall when strong northwesterly winds occur. The density-driven component is greatest in early summer when the surface freshwater input through runoff and ice melt is high. It is weakest between February and May, when surface freshwater input by runoff is reduced and is offset by the salt rejected by the growing ice, and when the ice cover limits wind stress and insulates the surface water.

Passing weather systems generate 5 to 6 day periodic motions that dominate the mean daily currents (Prinsenberg 1986b, 1987). These long-period motions are pressure-driven (barotropic) and decrease slightly with depth. They have amplitudes of up to 25 $cm \cdot s^{-1}$ and occur throughout the year, regardless of the ice condition. The mean hourly currents are dominated by pressure-driven tidal components of up to 28 $cm \cdot s^{-1}$ in amplitude. Storm winds can generate inertial currents that are as strong as the tidal currents but rotate clockwise, opposite to the tidal current direction. These wind-generated currents decrease with depth and are absent when Hudson Bay is ice-covered.

The mean residence time for water in Hudson Bay is uncertain because the contributions of runoff, ice melt and surface water to the surface layers of Hudson Bay are difficult to quantify (Ingram and Prinsenberg 1998). It has been estimated at 3 to 4 years (Jones and Anderson 1994) and 6.6 years (Prinsenberg 1984, 1986a), based on summer river runoff and salinity data. However, these estimates do not consider other sources of fresh water, so the true residence time may be on the order of one to two years (Ingram and Prinsenberg 1988).

The presence of a thin mud veneer and an absence of current bedforms indicates that modern (erosive) seafloor currents are limited or absent throughout much of Hudson Bay (Josenhans and Zevenhuizen 1990). However, erosional furrows in modern muddy sediments do evidence localized bottom currents at depths of 175 m offshore the La Grande River (Josenhans et al. 1991).

The circulation of water in the James Bay marine region is closely coupled with that in the adjacent Hudson Bay marine region. James Bay has a two-layer system of circulation consisting of an upper layer 20 to 50 m thick with a net outward flow, and a lower layer with a net inward flow (Prinsenberg 1982b). The summer circulation at the mouth of James Bay is characterized by a relatively slow mean inflow in the bottom layer and in the western half of the surface layer (2 to 5 $cm{\cdot}s^{-1}$), with a faster outflow (10 to 20 $cm{\cdot}s^{-1}$) concentrated in the eastern half of the surface layer (Figure 5-3; El-Sabh and Koutitonsky 1977; Prinsenberg 1982b, 1986b). Currents are generally faster in October than August. The net outward water transport varies between 65,000 $m^3{\cdot}s^{-1}$ in August and 167,000 $m^3{\cdot}s^{-1}$ in October, most of it along the east side (El-Sabh and Koutitonsky 1977). The estimated summer flushing time for James Bay is 10 months, with residence times of water in the surface (upper 10 m) and bottom layers of 3 and 7 months respectively (Prinsenberg 1982b, 1984). The winter residence time of 20 months is a reflection of the slower winter circulation.

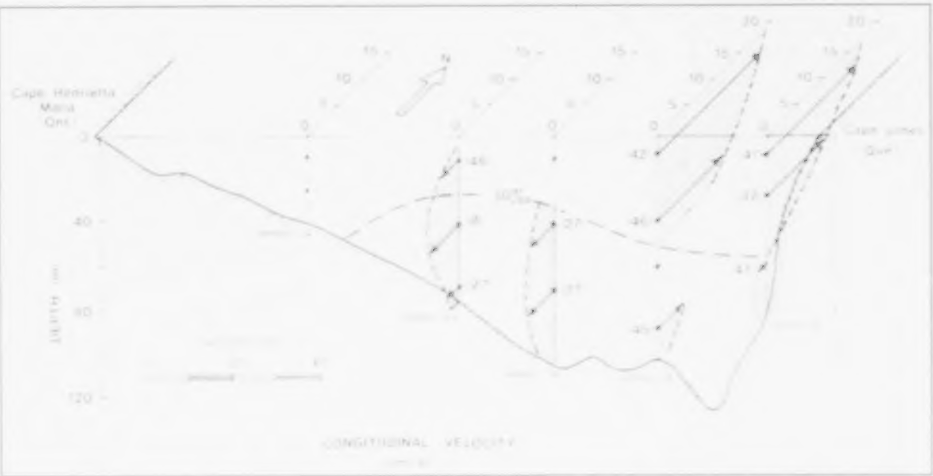


Figure 5-3. **Mean longitudinal velocity distribution during the summer of 1975 at the entrance to James Bay (from Prinsenberg 1982b, p. 828). Numbers in brackets indicate the length, in days, of the useable current meter record.**

The cyclonic gyre in northern James Bay continues year-round, driven partly by wind stress and partly by density differences due to runoff, with strong coastal jets on each side of the entrance (Peck 1976; Prinsenberg 1976, 1982b; 1986b; Wang et al. 1994a). Seasonal variations reflect the effects of both components of the circulation. As in Hudson Bay, passing weather systems can superimpose cyclic variations in the circulation at 4 to 6 day periods during the open water season. The magnitude of these variations depends upon the strength and directional persistence of the wind. A persistent southerly wind of about 8 $m{\cdot}s^{-1}$ (29 $km{\cdot}h^{-1}$) can reverse the surface outflow from James Bay. Once the Bay is ice-covered, the effects of wind forcing on the circulation are limited.

Runoff contributes to the dynamics of the James Bay circulation by diluting the salt water and creating density-driven currents. These currents are restricted to coastal waters (up to 50 km wide), and are greatest in early summer when runoff is high (Prinsenberg 1982a). Indeed, from summer to winter the magnitude of the density-driven currents at the inflow to James Bay decreases from 3.5 to 1.3 cm·s^{-1} and at the outflow from 15 to 5 cm·s^{-1} (Prinsenberg 1982a). Because the magnitude of density-driven currents is proportional to the runoff rate, hydroelectric developments that increase winter runoff will also increase winter circulation (Prinsenberg 1982a, 1991). Completion of the planned hydroelectric developments on rivers that flow into James Bay would double the total freshwater input into James Bay in winter (Prinsenberg 1980, 1991).

The pattern of water circulation in southeastern Hudson Bay is not well known, but there is a general movement of surface water east and north, following the cyclonic gyre that persists throughout Hudson Bay (Prinsenberg 1986b; McDonald et al. 1997). The area is affected by the part of the Hudson Bay water mass that continues eastward and northward instead of flowing southward into James Bay, and by the well-defined, surface current that flows northward along the eastern shore of James Bay. Part of the latter current crosses the mouth of James Bay to return southward with incoming water from the west; the remainder continues northward into southeastern Hudson Bay. Little is known of currents in Richmond Gulf.

Under-ice circulation has been estimated in early June near Kuujjuarapik using ice drift (Larouche and Dubois 1988, 1990). When there is less than 90% ice cover and floes are free to move, changes in ice floe movement are strongly correlated with the amplitude and direction of the wind, with a time lag that depends on the strength of the changing winds (Larouche and Dubois 1988, 1990). These wind-effects can be identified and removed to estimate the spring surface currents that are otherwise difficult to measure in the presence of moving ice. This method provided an estimate of 28 cm·s^{-1} for current near the southeastern coast of Hudson Bay in early June, but it has not been used to study under-ice currents elsewhere in Hudson Bay.

Knowledge of marine currents is important to Inuit, who travel on the water and ice and harvest birds and marine mammals that depend upon currents for access to food resources (McDonald et al. 1997). Maps based on their traditional knowledge of surface currents in eastern Hudson Bay and James Bay are closely similar to those prepared by oceanographers. Inuit recognize that the current strength varies from year-to-year but believe that there has been a general weakening of the surface currents since the 1950's. In support of this view, they have described a progressive increase in the ice cover in southeastern Hudson Bay that reduced the number of polynyas that remain open year round in the Belchers from 35 in the 1970's to 3 in the early 1990's. They are now able to cross Roes Welcome Sound, between western Southampton Island and the mainland, during the summer spring tide and, in 1992, a large polynya that seldom froze in January began freezing over in November and December. In some areas the floe edge has moved offshore and the strength and behaviour of the ice edge has also changed. Inuit wonder whether changes in the seasonality of river flows, caused by hydroelectric developments, have weakened the currents.

5.2 TIDES

Powerful tides surge into Hudson Bay twice daily via Hudson Strait (Dohler 1968; Drinkwater 1988). These semidiurnal tides originate in the Atlantic Ocean and overshadow local tides and any tidal influence from the Arctic Ocean. The main tidal constituent, the M_2 (principal lunar), is a Kelvin wave that propagates counterclockwise around Hudson/James Bay following the contour of the shoreline (Figure 5-4; Godin 1972; Freeman and Murty 1976; Prinsenberg and Freeman 1986). Part of the wave enters James Bay while the remainder, which is reduced in amplitude, continues northward along the east coast. As it passes south of the Belcher Islands, reflection from the shallow bar to the south produces a standing wave pattern. Offshore, in west-central and east-central Hudson Bay, components of the wave interfere and cancel each other, creating areas where there is little if any change in water level. When it joins the incoming tide in northern Hudson Bay, some 25 hours after it first entered, the wave is 10% of its original amplitude.

The damped progressive wave that enters James Bay is slowed in the vicinity of Akimiski Island, where it divides (Manning 1950; Godin 1972; Martini and Grinham 1984). One segment swings east around the island while the other is funnelled through Akimiski Strait. The Ekwan Shoal area of Akimiski Strait experiences the

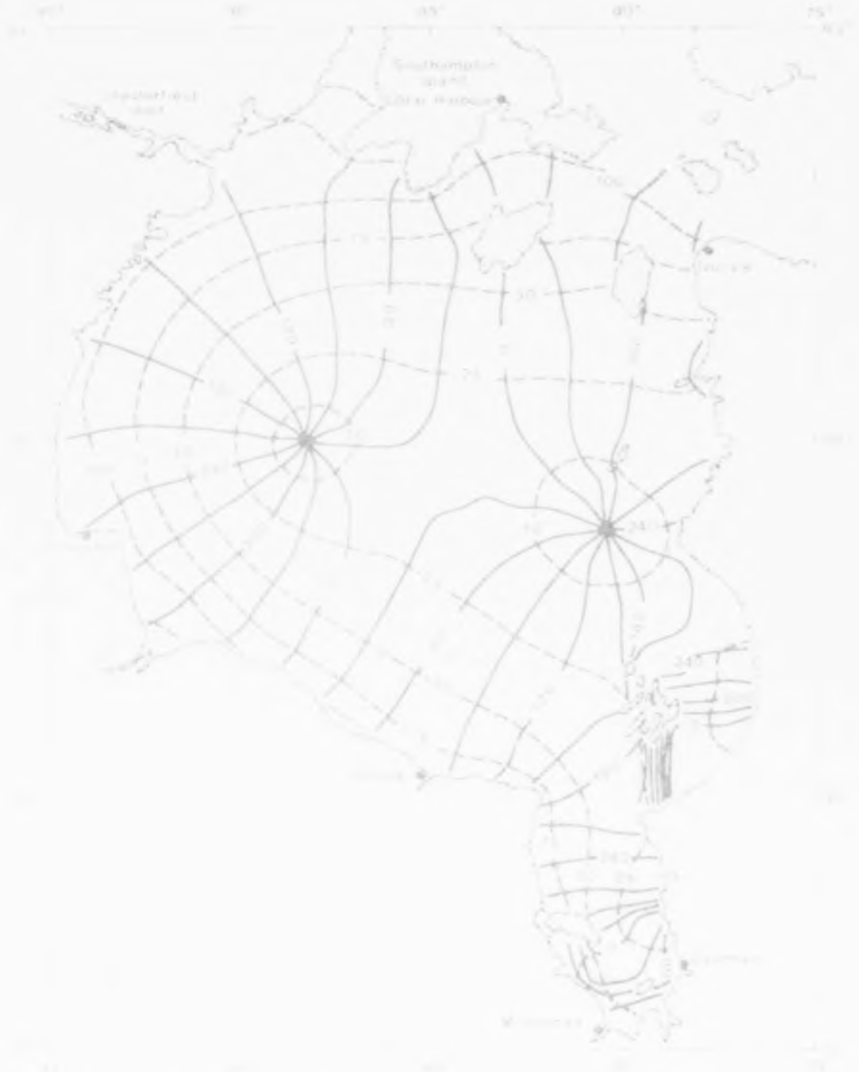


Figure 5-4. **Lunar semidiurnal (M2) tide in Hudson Bay and James Bay calculated by Freeman and Murty (1976) (from Ingram and Prinsenberg 1998 p. 854). Solid lines represent cophase lines in GMT + e (degrees); dashed lines represent co-amplitude lines (cm).**

highest tides (2.5 to 3.0 m) and fastest alongshore tidal currents (220 cm·s^{-1}) of western James Bay (Martini and Grinham 1984). The low areas between the shoals and mainland are swept and reworked by relatively powerful reversing currents created by strong flood tides that ebb out both ends of the Strait. Ice blocks the passage of tides through the Strait from November through late June (Martini 1981b). There is a degenerative node in east-central James Bay, opposite Akimiski Island, where the incoming and outgoing tides partially cancel one another (Godin 1972).

The tide reaches Rupert Bay seven hours after it rounds Cape Henrietta Maria (Godin 1972). Tidal flow in the shallow Rupert Bay estuary is strong, and there are numerous frontal zones wherein large gradients in physical properties occur (Veilleux et al. 1992). Typical tidal speeds are 50 to 150 cm·s^{-1} (Ingram 1977). The average tidal range is about 2 m at the mouth of the bay decreasing to 1.3 m at its head--2.9 and 1.9 m respectively for spring tides (d'Anglejan 1980). The daily tidal excursion is about 10 m. Intense mixing creates homogeneous conditions in many areas (Veilleux et al. 1992). The tidal fronts are parallel to the principal channels or around small downstream islands, with the arrangement influenced by topography. Seasonally, the extent of salt intrusion does not appear to differ between the river flood stage and the low-water winter stage, since tidal friction under the ice cover approximately balances the reduction in freshwater discharge (Michel 1978 in d'Anglejan 1980). Salt is not introduced very far by the average tide--never beyond Stag Rock (d'Anglejan 1980).

Tides in the Hudson Bay marine ecosystem are classified as semidiurnal but there is also a weak diurnal tide (Prinsenberg and Freeman 1986). In general, both tidal amplitude and range decrease progressively moving counterclockwise along the coast (Dohler 1968; Prinsenberg and Freeman 1986). The extreme tidal ranges and velocities found in eastern Hudson Strait are not found in either bay. The semidiurnal tidal amplitude ranges from 1.50 m along the western shore at Churchill to 0.10 m along the eastern shore near Inukjuak, while the diurnal tide is only 0.08 and 0.03 m at the respective locations (Figure 5-4; Prinsenberg and Freeman 1986; Prinsenberg 1988a). The range in height between high and low water also changes around the bays, increasing from 3 m near the entrance of Hudson Bay to a high of 4 m along the west coast at Churchill Harbour and then decreasing to about 2 m along the east side of James Bay and in the Belchers and to 0.5 m at Inukjuak (Inoucdjouac) (Dohler 1968; Godin 1974). Tidal currents of 90 to 100 $cm \cdot s^{-1}$ have been measured at the entrance to Hudson Bay; within the bay they are generally less than 30 $cm \cdot s^{-1}$ (Dohler 1968; Prinsenberg and Freeman 1986). The tidal streams are strongest in the western part of the bay. Tidal currents of 50 $cm \cdot s^{-1}$ have been measured at the entrance to James Bay (Prinsenberg and Freeman 1986), and they can reach 80 $cm \cdot s^{-1}$ near Sand Head in the Moose River estuary at spring tide (Godin 1972). Unlike wind-generated currents the tidal currents recur daily and decrease slowly with depth.

Using a two-dimensional model of the semidiurnal tide, Griffiths et al. (1981) predicted that the tidal currents in central Hudson Bay are too weak to disrupt water column stratification during the summer. They also predicted vertical mixing of the water column and increased biological productivity on a small-scale off islands, headlands, and promontories where there is locally increased tidal streaming. Areas they identified included Frozen Strait, the entrance and exit to Roes Welcome Sound; the entrance to Wager Bay; waters offshore Cape Kendall and Cape Low on Southampton Island, Cape Acadia on Mansel Island, Cape Churchill, and Cape Henrietta Maria; Rankin Inlet; the Nelson River estuary; and western James Bay, particularly downstream from Akimiski Island. However, their model did not take into account wind mixing or the stabilizing effects of runoff, and thus may only be applicable to offshore regions of Hudson Bay (Prinsenberg and Freeman 1986).

Three factors may affect the regularity of the tides, the spring freshet, ice cover, and weather disturbances. During April-May ice breaks up in the rivers surrounding James Bay and their discharge increases abruptly (Godin 1972). This increase inhibits tidal penetration into the rivers and a wall of freshwater may extend well into James Bay, where the tide is reduced in range and the mixing of salt and fresh water intensifies. Ice cover damps the tide and advances the time of arrival of high water and flood current (Godin 1980, 1986; Godin and Barber 1980; Ingram 1982; Prinsenberg and Freeman 1986; Prinsenberg 1988a; Lepage and Ingram 1991; Prinsenberg and Ingram 1991). Semidiurnal tides in western Hudson Bay arrive 20 minutes earlier in winter than summer and show a 7 to 10% reduction in current and height; at Chisasibi, in eastern James Bay, they also arrive 20 minutes earlier in winter than summer but show a 30% reduction in amplitude (Godin 1986). The seasonal fluctuations are even greater at Inukjuak--where the tides arrive 40 minutes earlier in winter, probably due to displacement of the point of amphidromy by ice formation. Diurnal tides are similarly but less predictably affected. Weather induced tidal storm surges are discussed below.

Recent modelling of the ice-ocean seasonal cycle suggests that tides are an essential control on the regional pack ice and ocean climate of Hudson Bay (Saucier et al. 2004a). They suggest that tidal mixing controls the sensible heat transfer, thereby reducing sea ice formation, and is responsible for maintaining the coastal polynyas.

Chesterfield Inlet is an estuary with stronger tidal currents, higher tidal amplitudes, and a greater degree of mixing than elsewhere in Hudson Bay (Dohler 1968; Budgell 1976, 1982). It has tidal ranges of 5 m at spring tides and 2 m at neap tides in the lower third of the estuary, and of 3 m and 1.5 to 2 m over the remainder of the estuary (Budgell 1982). There is a strong tidal influence up to the entrance of Baker Lake where the combination of tidal dissipation at a shallow sill and the sharp increase in cross sectional area reduce the tidal range to less than 0.10 m. Tidal current in the inlet is reversing. Amplitudes of over 100 cm·s^{-1} are observed throughout the channel, with current speeds of 150-200 cm·s^{-1} near channel constrictions. The tidal streams at Chesterfield Narrows are strongly influenced by the freshwater outflow from Baker Lake (Dohler 1968) and the tides in turn likely contribute salt water to Baker Lake, which has a bottom layer of very dilute seawater (Johnson 1965).

5.3 WAVE CLIMATE AND STORM SURGES

Data on wave heights and periods in Hudson Bay and James Bay are scant. They suggest median August and September wave heights in Hudson Bay of 1 to 2 m with periods of 5 to 6 seconds (Maxwell 1986). During the open water season, wave heights over 3 m occur about 10 % of the time in northern Hudson Bay, with most of the largest waves originating from the northwest (Cohen et al. 1994). Wave heights of 8 m with periods of 10 seconds have been recorded in September in northern Hudson Bay (Maxwell 1986).

Strong storm surges sometimes occur in southern James Bay (Manning 1951; Godin 1972, 1975). These surges are most likely to occur during the storm seasons, namely between September to December and April to June. They pose a significant hazard to travellers who may be unprepared for a tide that can extend kilometres inland beyond the normal high water mark (Godin 1975). Murty (1972) predicted that if there were an 89 km·h^{-1} (51 mph) wind along the north-south axis of James Bay the amplitude of these surges could reach up to 6 m (18.8 ft) along its southern shores.

5.4 SEA ICE

The presence of winter ice cover is a very important feature of the Hudson Bay marine ecosystem. Its southern extent and the presence of extensive areas of fast ice are unusual and strongly affect the physical and biological oceanography, the surrounding land, and human activities. The reliance of Inuit and coastal Cree on sea ice for travelling and hunting is reflected in their detailed knowledge of its processes, characteristics, and annual cycles (McDonald et al. 1997). The sea ice determines the ecology of the ice biota and it also influences pelagic systems under the ice and at ice edges (Melnikov 1980; Legendre et al. 1992a). As the interface between air, ice, and water, ice edge habitats are areas of mixing that attract biota to feed. These areas are important sites of energy transfer within the ecosystem. Unlike marine regions to the north, Hudson Bay and James Bay are ice free in the summer.

During ice growth, most of the original seawater is rejected from the ice. The rejected salt increases the density of the surface water, which then enhances the deepening of the surface mixed layer by tidal current mixing (S. Prinsenberg, DFO, Darmouth, NS, pers. comm.). The surface layer deepens at places to 100 m, thus distributing the rejected salt to most of the water column. In contrast during the spring, the melting of the ice cover constitutes a freshwater flux to just the ocean surface layer, increasing the vertical stability of the water column and decreasing the vertical nutrient flux. If the pack ice did not move, the ice growth and decay would represent a salt flux to the total water column in the fall and winter, and a freshwater flux to the surface layer in the spring and early summer. However under predominantly northwest winds, the pack ice continually removes the ice from northwestern Hudson Bay and moves it to southeastern Hudson Bay where it rafts and ridges. These pack ice processes increase the mean spatial ice thickness in southeastern Hudson Bay (Prinsenberg 1988b), which in the spring represents a large freshwater input from the decaying ice cover. In northwestern Hudson Bay, in contrast, the ice is continually removed, encouraging new ice growth and continual salt input to the water column. Numerical simulations duplicate these pack ice properties (Saucier et al. 2004a). Sea ice begins to form in northwestern Hudson Bay and ice generally moves towards the southeast in early winter where it ridges to mean a thickness of 1.5 to 2.0 m by April. Thinner ice is simulated for northeastern Hudson Bay. Monthly mean ice drift velocities range from 10 $\text{cm}\cdot\text{s}^{-1}$ in northwestern Hudson Bay to 1 $\text{cm}\cdot\text{s}^{-1}$ in southeastern Hudson Bay where higher ice concentration and ridging occurs. The strong northwest winds and tidal mixing encourage the reoccurring leads and polynyas along the western shore of Hudson Bay.

Recent advances in satellite technology have facilitated detailed studies of winter sea ice in Hudson Bay and James Bay. Unless otherwise noted, the description that follows is based on two informative publications by W.E. Markham (1986, 1988), with updated information from Cohen et al. (1994). Markham's latter publication, an "Ice atlas of Hudson Bay and Approaches", is based on the interpretation of at least 20 years of summer and 6 years of winter ice data that were collected by satellite on a weekly or biweekly basis. Some useful earlier studies include: Low (1906), Hare and Montgomery (1949), Larnder (1968), and Danielson (1971).

Differences exist between conventional and passive microwave sea ice datasets for Hudson Bay (Etkin and Ramseier 1993). The conventional datasets, which are based on direct observation, are more accurate during the spring melt when meltwater ponding on the ice is mistaken by the remote sensing algorithms for open water. They are less accurate during freezeup when it is difficult to observe the presence of new ice. Remote sensing has also tended to underestimate the density of older pressure ridges that are obscured by snow cover (Hudier et al. 1993).

5.4.1 Terminology

During the cycle of ice formation and decay, sea ice may pass through a number of stages. From the time ice crystals begin to form slush at the surface until they coalesce the sea ice is termed **new ice**. Once the crystals coalesce into ice with a definite form the ice is termed **young ice**. Initially it forms a 5 to 10 cm thick elastic layer that tears rather than breaks when penetrated by a ship, and that bends on waves. The young ice loses its elasticity as it thickens from 10 to 30 cm. The final stage of ice growth in the area is **first year ice**. It can be thin (30-70 cm), medium (70-120 cm), or thick (120-200 cm) depending on the temperature regime. Ice that has survived one or more summers after its formation is termed **old ice**. Old ice is often 2 or 3 m thick and is harder than first year ice because it is nearly salt-free. It poses a greater hazard to ship navigation but seldom penetrates southward into Hudson Bay and James Bay.

Normally, ice forms first in shallow water areas. If it remains attached to shore it is termed **fast ice** (or **landfast ice**) and if it is carried away by wind, tide or current, **drift ice**. Drift ice and **pack ice** are synonymous, but pack ice is generally reserved for situations when 7 to 10 tenths of the water surface is covered by ice. When ice floes are pressed together by wind or current their edges may overlap. This **rafting** is most common on young ice. Ice fragments are forced upward and downward when thicker first year ice grinds together. When this occurs along a continuous edge it forms **pressure ridges**, and when it occurs in one area a **hummock**. A pressure ridge that is 1.0 m in height may extend 4 or 5 m below the ice floe, and poses a hazard to surface and submarine navigation.

This is a much simpler system of describing ice conditions than that used by Inuit, who use 71 distinct terms to describe each different ice condition through five stages of development (McDonald et al. 1997). Inuit knowledge of ice development is important for the assessment of how predicted changes in climate are affecting sea ice, locally and in the Hudson Bay marine ecosystem as a whole (see Chapter 17).

Ice cover is determined mainly by the amount of heat exchanged between ice, water, and air. These processes are complex and often difficult to measure. The number of degree days when the mean air temperature is greater than (melting degree days) or less than (freezing degree days) 0°C are useful indicators of the heat exchange. The ice conditions in Hudson Bay and James Bay are very variable early in the season when warm or cold spells can have a relatively great impact on the number of freezing or melting degree-days. Wind and the presence of cold incoming Arctic waters in the northwest are also important determinants of the ice cover.

5.4.2 Seasonal Changes

Markham used median rather than mean ice concentrations to describe ice cover. This has the advantage of representing the mid-point in the range of observed conditions rather than the mathematical average, which may rarely occur.

Median ice concentrations in the Hudson Bay marine ecosystem begin to increase in October in the Repulse Bay area and during November the ice cover spreads rapidly southward along the western coast of Hudson and James bays and then, more slowly, eastward (Figure 5-5). From November through late June ice impedes circulation and tides in Akimiski Strait (Martini 1981b). It causes the Strait to behave as an ice-walled bay, largely forcing circulation and tides outside Akimiski Island.

By mid-December the region is between 9 and 10 tenths ice-covered. Fast ice fills bays along the west coast of Hudson Bay south to Arviat and along the west coast of James Bay from Akimiski Island south to Rupert Bay, and forms around the Ottawa and Belcher islands. Ice growth has reached 65 cm at Chesterfield Inlet, Coral Harbour, and Churchill. There is a steady growth in ice thickness from January until April, with the ice cover remaining in the range of 9 to 10 tenths. In southeastern Hudson Bay, the conolidation of the pack into fast ice normally occurs between mid-January and mid-March (Larouche and Galbraith 1989).

The development of extensive areas of fast ice is an important feature of the ecosystem. By the end of April the fast ice edge south of Rankin Inlet has moved further offshore and extends in a narrow strip southward from Arviat to Churchill (Figure 5-6). There is a band of fast ice along the south coast of Hudson Bay from York Factory to Cape Henrietta Maria and along the entire coast of James Bay; the Ottawa, Belcher and King George archipelagos are surrounded; and there is a wide band of fast ice along the eastern shore from Cape Smith south to Pointe Despins. It is common for fast ice to cover much of southeastern Hudson Bay and surround the Belcher and King George archipelagos for part of the season. Indeed, in some cold winters the whole area from Cape Jones to the Belchers to the Ottawas to Cape Smith becomes one consolidated mass for a short period. The western extent of fast ice cover in southeastern Hudson Bay, between Kuujjuarpik and the Belcher Islands, appears to be controlled mainly by wind and temperature (Larouche and Galbraith 1989). During the freezing period, strong southwesterly winds can reduce the consolidation of the pack ice into fast ice in this area and, on rare occasions, melting conditions can largely prevent fast ice from extending away from the mainland coast.

Maximum ice cover occurs in April and May when the median ice concentrations are high and the ice thickness nears its peak. Depending upon the year and location, the maximum ice thickness can occur between late February and early June and range from 71 cm at Moosonee to 285 cm at Inukjuak (Table 5-2). Modelling studies suggest that changes in runoff have a greater effect on the interannual variability of the ice cover than do temperature changes associated with the North Atlantic Oscillation, especially in southeastern Hudson Bay (Saucier and Dionne 1998). However, most of the variability in ice cover is likely related to differences in the summer and autumn winds, air temperature (which control heat loss and winter preconditioning), spring cloud cover (which controls heat gain), and snow cover (which controls the winter insulation). By the end of April the fast ice edge south of the Belchers is beginning to recede.

The ice floes are kept in constant motion by the wind. Leads develop when the winds blow offshore and are quickly covered by new and young ice. These leads are important habitat for species such as the Hudson Bay eider and longtailed duck that overwinter in the region, and to migratory birds and mammals that arrive early in the spring (Prach et al. 1981; Nakashima 1988; Stirling 1997; Gilchrist and Robertson 2000). There are recurring leads along the west shore of Hudson Bay from Churchill to Chesterfield Inlet and Coral Harbour, and elsewhere along the fast ice edges. Open water that occurs along fast ice edges in the Belchers is not present during severe winters (Gilchrist and Robertson 2000).

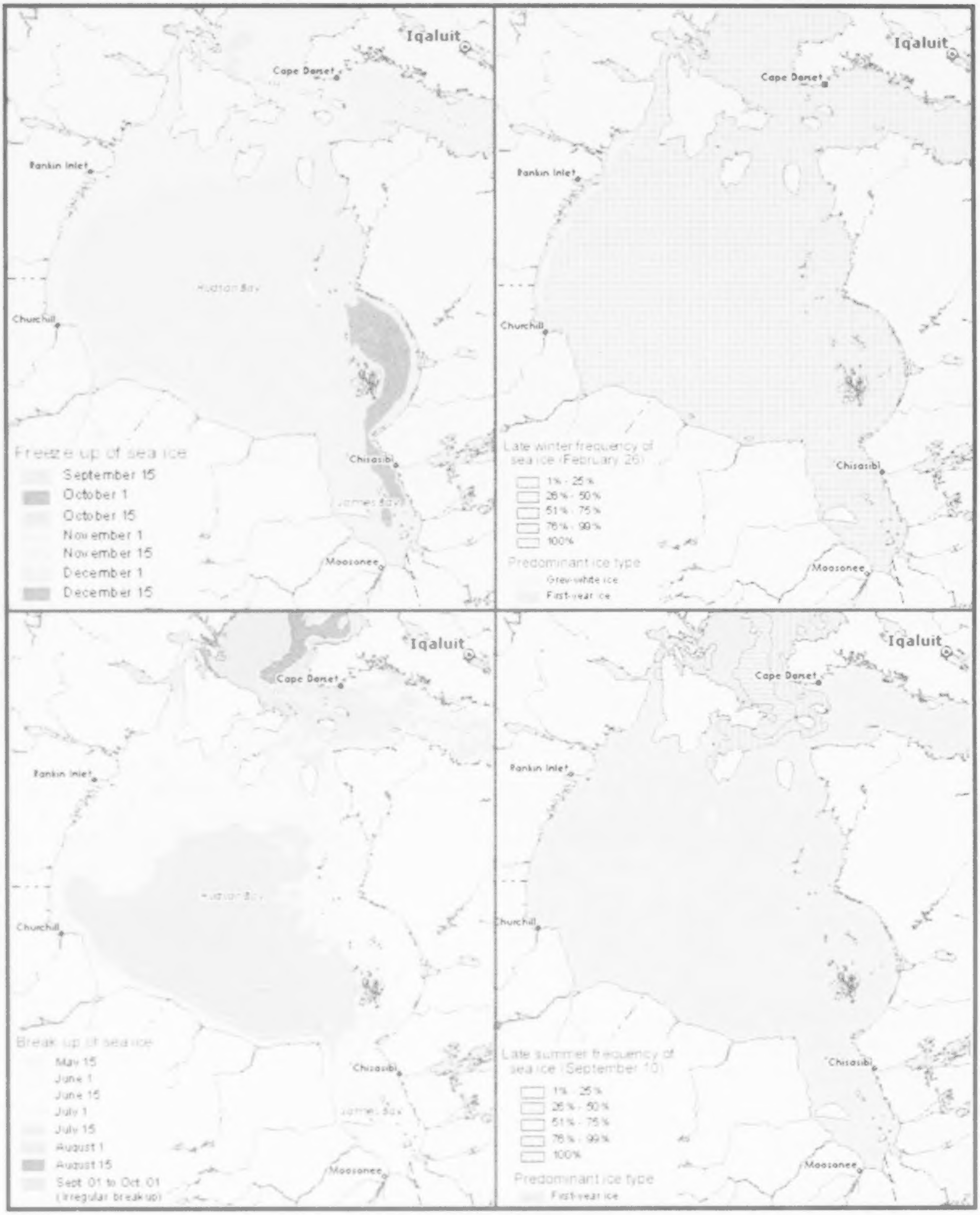


Figure 5-5. **Patterns of sea ice freeze-up (top left) and break-up (bottom left) and frequency and type of late winter (top right) and late summer (bottom right) sea ice, based on 30 years of data (adapted from National Atlas of Canada 2003).**

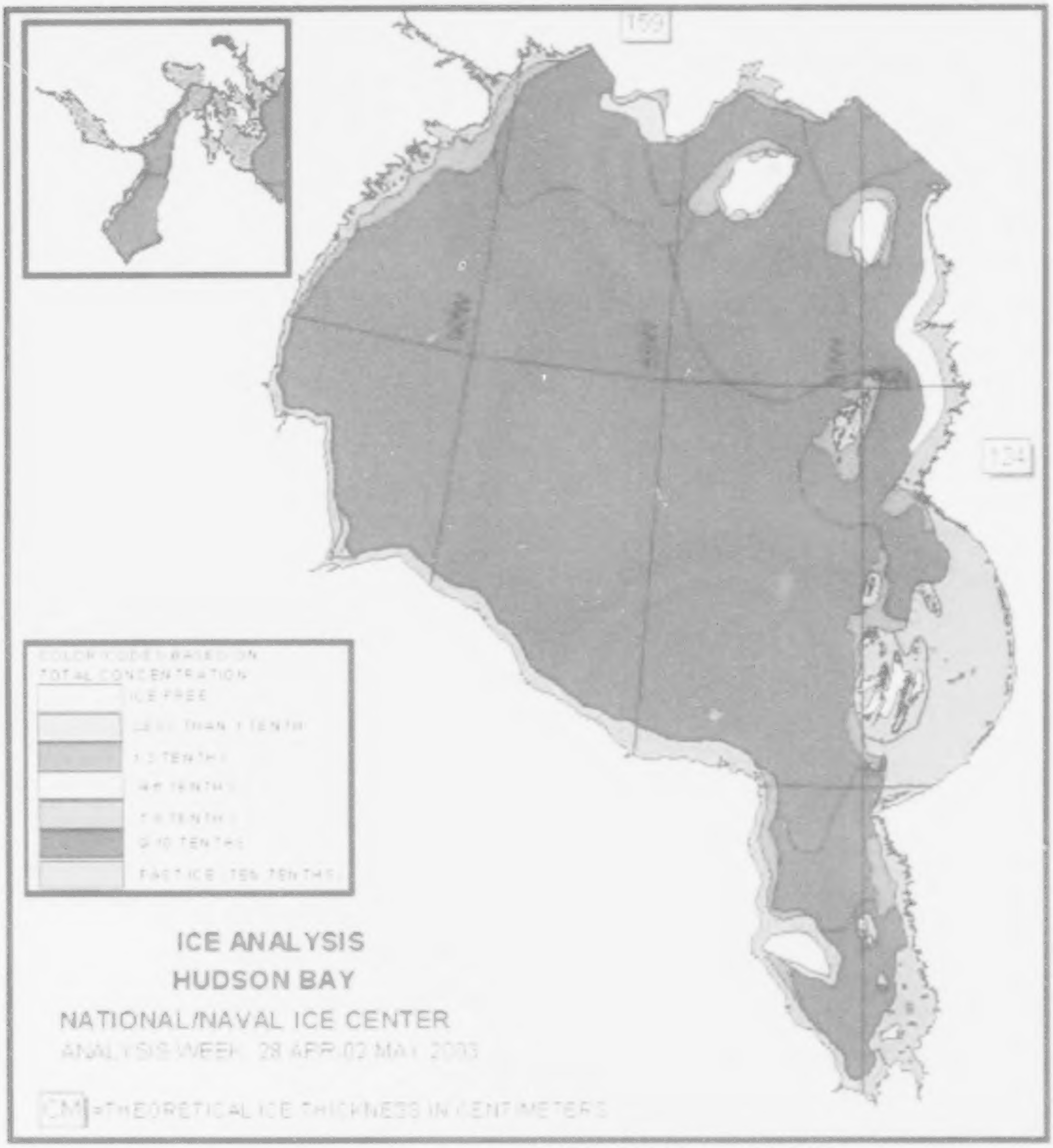


Figure 5-6. Sea ice concentration in the Hudson Bay marine ecosystem during the week of 28 April to 2 May 2003 (from NOAA 2003).

Table 5-2. **Range of maximum ice thickness (augmented by 10% of snow cover) over the period 1963-83, corresponding range of dates, and range of dates of open water (from Loucks and Smith 1989).**

Community	Maximum ice thickness (cm)	Date (Julian days)	Date of open water (Julian days)
Coral Harbour	143-208	114-162	177-213
Chesterfield Inlet	163-226	101-158	178-210
Inukjuak	176-285	71-157	156-189
Churchill	138-207	49-151	122-200
Kuujjuarapik	113-220	84-124	141-154
Moosonee	71-130	114-162	177-213

Small recurring polynyas are present in the Belchers and near islands along the coast of southeastern Hudson Bay (Figure 5-7), in Roes Welcome Sound, at the northern tip of Coats Island, near Digges Island, and just off the southwest tip of Akimiski Island (Martini and Protz 1981; Stirling and Cleator [ed.] 1981; Nakashima 1988; Gilchrist and Robertson 2000). The latter polynya is one of the most southerly in Canadian seas. These openings in the sea ice are vitally important to overwintering species and to early spring migrants. They are often areas of increased biological productivity.

Ice ridges and hummocks are formed in pack ice regions where its drift is restricted by shores. Ice ridges are common in northern and southern Hudson Bay and in James Bay, with 4 to 10 ridges·km^{-1} (see also Prinsenberg 1988a). Twenty-six percent are over 1 m in height and they can reach heights of 3 to 3.5 m. Ridges are less common and smaller in northwestern Hudson Bay due to the offshore drift.

In early June the coastal leads become broader and more persistent. Median ice concentrations fall to the open water state in Chesterfield Inlet and there is open water in southern James Bay. Lower median ice concentrations are also evident along the east shore of Hudson and James bays and in Roes Welcome Sound (see also Hare and Montgomery 1949). With the lengthening days the ice is melting everywhere by late June, and extended warm or cold spells or periods with clear skies can determine whether breakup is early or late. Sea ice in James Bay is often sediment-laden, and this discolouration hastens melting in the spring.

The same melting pattern continues in July. Reduced ice concentrations and partial clearing are apparent in northwestern Hudson Bay where winds tend to move the pack ice offshore, and in eastern Hudson Bay from the Belcher Islands to Mansel Island where the ice is melted in place by the northward flow of spring runoff from James Bay (see also Markham 1976).

By mid-July the pack is located in the area from Churchill to the Belcher Islands to Mansel Island. While the median concentration is still 6 to 8 tenths, it has decayed to the point where it no longer poses a hazard to navigation. The actual amount of ice and its location varies widely at this time of year depending on the winds. Indeed, in some years the pack has been located off Chesterfield Inlet. Because ice in the floes is relatively flat there is extensive puddling or ponding on the surface during the melt period and, because the thickness is relatively uniform, large areas of ice melt within a very few days. The median ice concentration reaches open-water conditions in the first week of August and continues until freeze-up in the fall except in the Repulse Bay area, which receives ice from Foxe Basin (Figure 5-5).

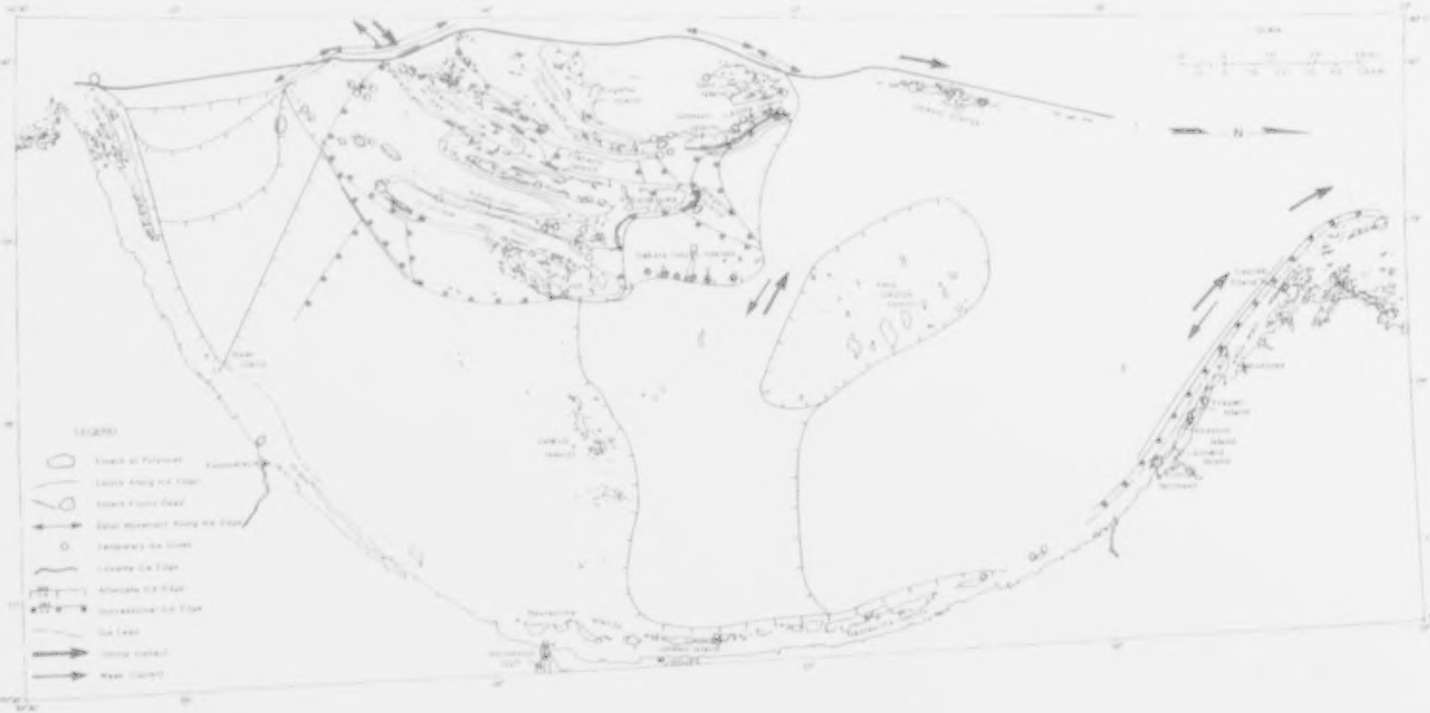


Figure 5-7. Winter ice formation and eider distribution in southeastern Hudson Bay (from Nakashima 1988).

Depending on weather conditions, the timing of freeze-up or breakup may be retarded or advanced by up to a month, but the basic pattern of ice formation remains similar (see also Barber 1972). In 1816, for example, open ice lingered a month longer than usual in northern James Bay and northwest of the Belchers (Catchpole and Faurer 1985). The extent of the fast ice also varies. In some winters, the whole area from Cape Smith to the Ottawa Islands to the Belcher Islands to Cape Jones can be covered by fast ice. The inter-annual variability of sea ice in Hudson Bay is related to large-scale atmospheric circulation changes (Wang et al. 1994c; Mysak et al. 1996). During strong winter westerly winds of the North Atlantic Oscillation and Low/Wet summer episodes of the Southern Oscillation, the sea ice grows thicker and breakup is delayed. While ice area has been directly correlated with runoff volume the previous year (Manak and Mysak 1989; Wang et al. 1994c), a direct cause-effect relationship between the two parameters has not been well established (see also Saucier et al. 2004a). Throughout Hudson Bay and James Bay, the melt period is longer and more variable in its timing than the freezeup period (Figure 5-8; Cohen et al. 1994).

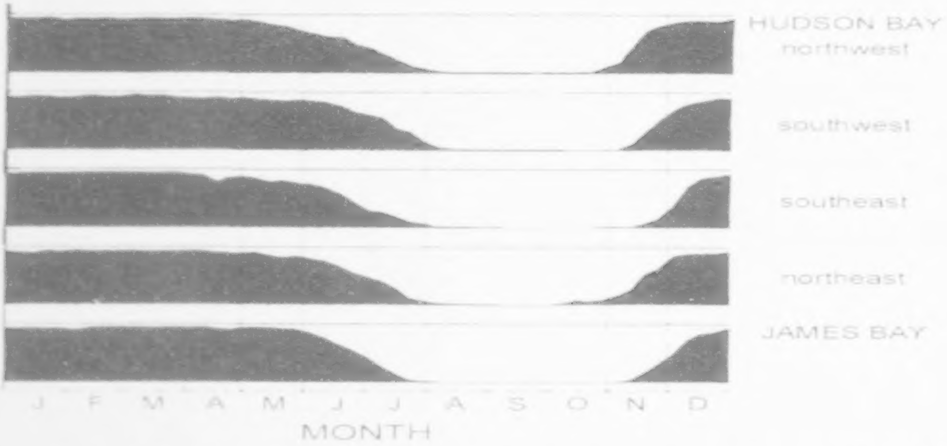


Figure 5-8. **Mean ice concentrations (1972-88) by month for locations in Hudson Bay and James Bay (modified from Cohen et al. 1994).**

Old ice and icebergs are rare in Hudson Bay and rare or absent James Bay. There are incursions of old ice from Foxe Basin to just south of Coats and Mansel islands between 1% and 25% of the time in October, and on rare occasions it penetrates southward to Arviat (see also Fleming and Newton 2003). An iceberg has been reported in the Mansel Island area.

The importance of sea ice to the Hudson Bay marine ecosystem and its vulnerability to climatic warming have spurred efforts to develop a mathematical model that accurately simulates the region's sea ice dynamics (Wang et al. 1994b, 2003; Saucier and Dionne 1998; Senneville et al. 2002; Gachon and Saucier 2003; Saucier et al. 2004a). This work is enabling oceanographers to test the relative importance of strong westerly winter winds created by the North Atlantic Oscillation, anomalous high runoff, hydroelectric regulation of runoff, strong autumn winds or low autumn surface air temperatures, climatic warming, tidal forcing, and other factors that affect the sea ice. The modelling results suggest that autumn winds and air temperatures may have a greater effect on the thickness of sea ice than either strong winter westerlies, or regulated runoff conditions (Saucier and Dionne 1998). They also suggest that tidal mixing, which controls sensible heat transfer, is an important factor limiting winter sea ice volume and creating polynyas (Saucier et al. 2004a). The location of the sea-ice margin in turn appears to affect the deepening and tracking of polar lows that form over Hudson Bay (Gachon et al. 2003).

5.5 SALINITY, TEMPERATURE, AND MIXING

The distributions of salinity and water temperature in Hudson Bay and James Bay vary seasonally with changes in the freshwater runoff, ice cover, and surface heat flux (Prinsenberg 1986a). These changes are not well understood since there is no complete set of temperature-salinity transects that covers the entire area in any season, most sampling has been conducted during the open water season, and few studies have been repeated in subsequent years.

Roff and Anderson (1980a; n = 158 sites) and Prinsenberg (1986a; n = 200 sites) prepared salinity and temperature distributions for Hudson Bay using data collected in August and September 1975 (Figure 5-9). These are the most comprehensive single-season distributions available and form the basis for much of the following discussion. They are somewhat different from the distributions prepared by Barber (1967), which are composites based on data collected by various studies during the open water period in the 1950's and 1960's (Figure 5-10). The year-to-year variability of the surface salinity and temperature distributions is unknown but differences between studies suggest that it may be substantial (see Barber 1967; Anderson and Roff 1980a; Prinsenberg 1986a; Drinkwater et al. 1994). Some under-ice data are available from coastal waters near the mouths of the Eastmain, La Grande, and Grande Baleine rivers and from northern James Bay and Manitounuk Sound.

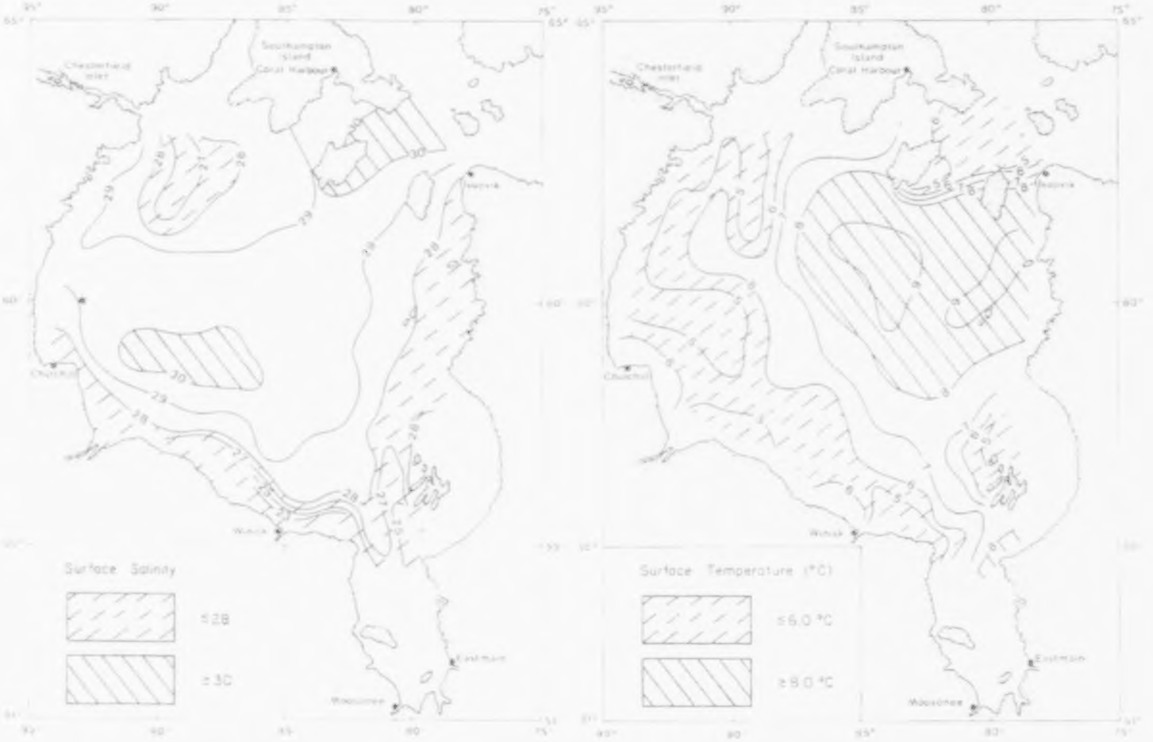


Figure 5-9. **Surface salinity and temperature distribution of Hudson Bay in August-September 1975 (adapted from Prinsenberg 1986a).**

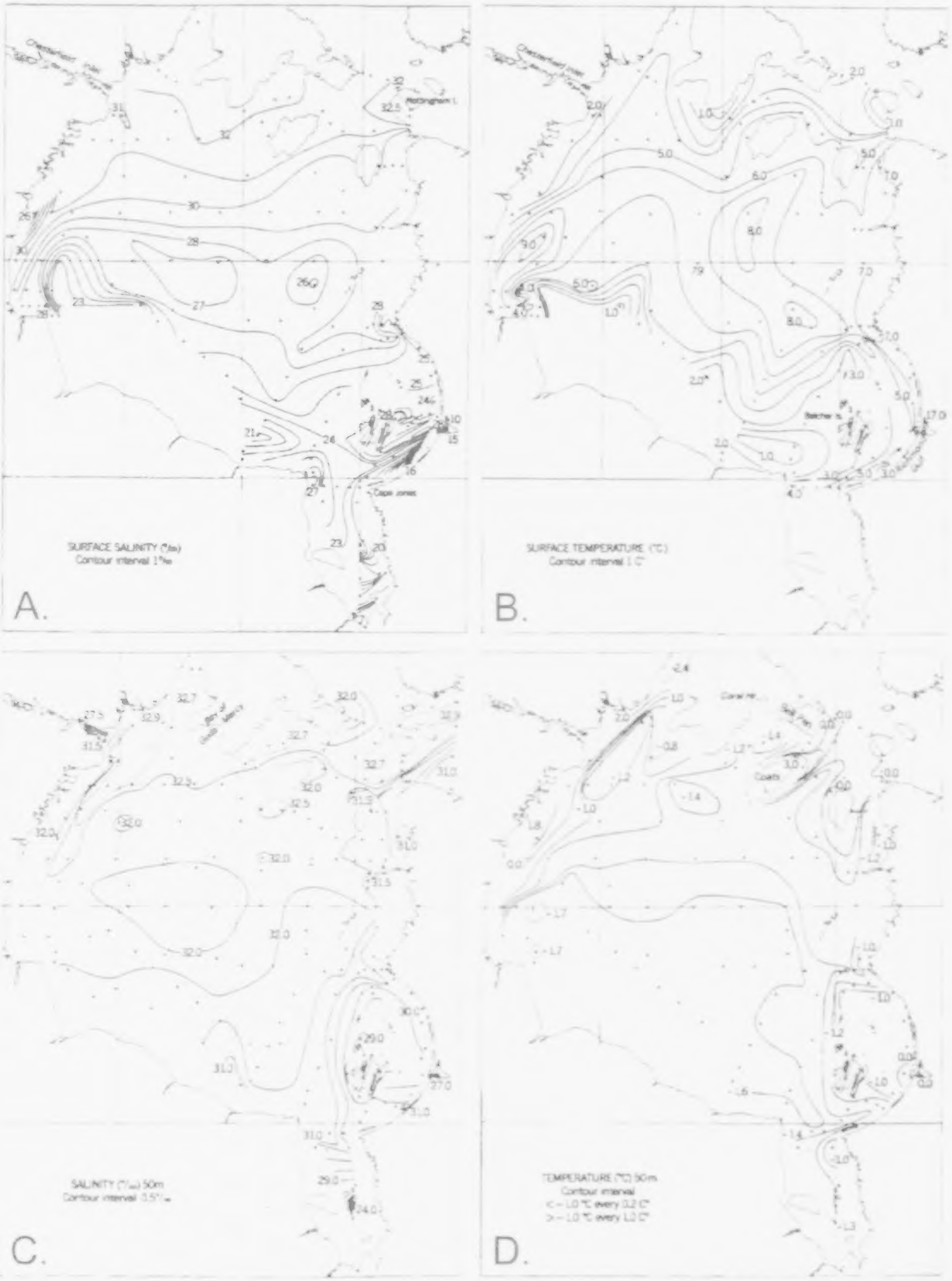


Figure 5-10. Distribution of salinity (A) and temperature (B) at the surface and salinity (C) and temperature (D) at 50 m depth from data observed during the open water season by a number of sources (adapted from Barber 1967). Dots indicate sampling stations.

5.5.1 Surface Distributions

During the summer, cold, saline surface water that enters Hudson Bay from the north is diluted by runoff and heated by solar radiation as it circulates cyclonically around Hudson Bay--some of it enters James Bay (Prinsenberg 1986a). This dilution and warming creates vertical density gradients that effectively prevent mixing of the surface and deep waters and thereby the transport of nutrients from the bottom waters into the surface waters. Strong vertical stratification is characteristic of the offshore waters of both Hudson and James bays during the summer and must limit biological productivity (Roff and Legendre 1986). In winter, lower runoff, salt rejection from the growing ice cover, and surface cooling weaken the vertical stratification and permit very slow vertical mixing. There is little coastal development or bottom relief to promote mixing or upwelling that might increase the availability of chemical nutrients in the surface waters.

In the Hudson Bay marine region, there is a general increase in temperature and salinity with distance offshore in the summer (Figure 5-9; Anderson and Roff 1980a; Prinsenberg 1986a; S. Prinsenberg, DFO, Dartmouth, NS, pers. comm.). In western Hudson Bay, the lower temperature inshore is attributed to the northwest wind, which causes upwelling and along with the strong tidal current mixing brings colder deeper water to the surface. The lower surface salinities there are due to dilution by freshwater runoff. In southern Hudson Bay the colder and low salinity inshore conditions are attributed to the pack ice that lingers there well into the summer months. In August and September 1975, salinities at 3 m depth ranged from about 23 to 30 ‰ (‰≈psu) and temperatures from 4 to 11°C. Salinities were highest offshore near the middle of Hudson Bay and between Coats and Mansel islands where the region borders on Hudson Strait. Inshore, the salinities were lower except along the west coast. The lowest salinities were found very close to shore adjacent to the Nelson River and distinct plumes were created by runoff from Chesterfield Inlet and the Churchill and Nelson rivers. Low temperatures were observed in the coastal waters of southern and western Hudson Bay and around the Belcher Islands. Higher temperatures, generally 8°C or greater, extended over a large area from the Quebec coast westward into the middle of the bay. They are attributed to solar heating of more stable surface waters.

Under the ice, salinity and temperature distributions in the Hudson Bay marine region are largely unknown. Surface distributions likely follow a similar pattern to those seen in the summer but with higher salinities and lower temperatures, and more extensive surface dilution by river plumes (Prinsenberg 1986a, 1987; Wang et al. 1994a; Ingram and Prinsenberg 1998). Below 50 m depth there should be little seasonal change in these distributions seasonally or from year to year.

Currents transport the relatively cool, low salinity surface water of southern Hudson Bay into northwestern James Bay in the summer (Figure 5-1 and Figure 5-2; Barber 1967, 1972; El-Sabh and Koutitonsky 1977; Prinsenberg 1986a). As it circulates counterclockwise around the bay the water is warmed by solar radiation and further diluted by runoff. This warming continues as the water exits to follow the eastern coast of Hudson Bay northward, and mixes with the more saline water of southeastern Hudson Bay. In the Belcher Islands area, offshore, the summer surface temperature is lower and the salinity greater than elsewhere in the James Bay marine region (Figure 5-10 and Figure 5-11). In contrast, the relatively sheltered surface water of Richmond Gulf is warmer, up to 17°C, and more dilute (Rochet and Grainger 1988). Similar high temperatures may occur locally in other sheltered areas.

The summer surface salinity values over most of James Bay and southeastern Hudson Bay are low relative to the rest of Hudson Bay, which itself is low relative to other seas. They range from less than 10 ‰ (‰≈psu) in southern James Bay and along the Hudson Bay coast south of Richmond Gulf to 28 ‰ around the Belchers, offshore the mouth of Richmond Gulf, and near Inukjuak (Figure 5-10 and Figure 5-11; Barber 1967, 1968; Prinsenberg 1986a). There is a relatively steep surface salinity gradient south and east of the Belchers where the more saline waters surrounding the Belchers meet the less saline waters exiting from James Bay. There are also steep salinity gradients in the vicinity of the major river outlets.

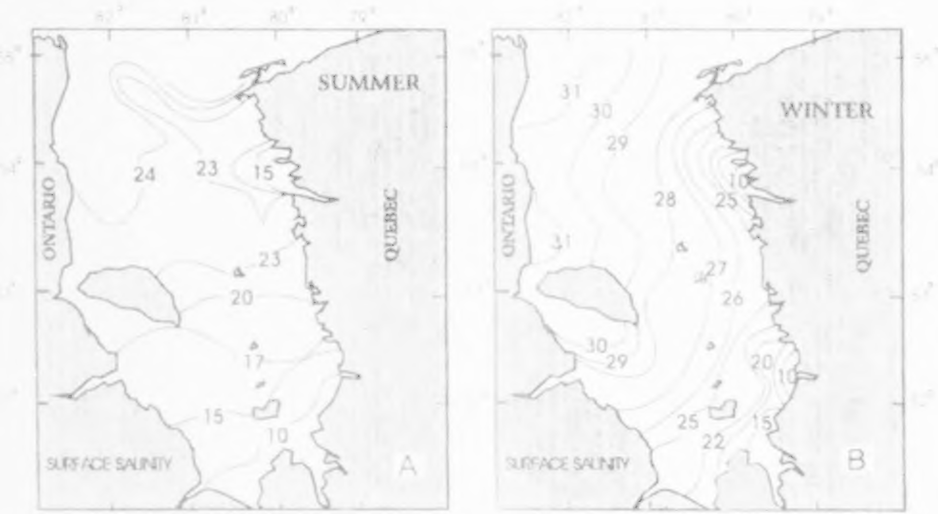


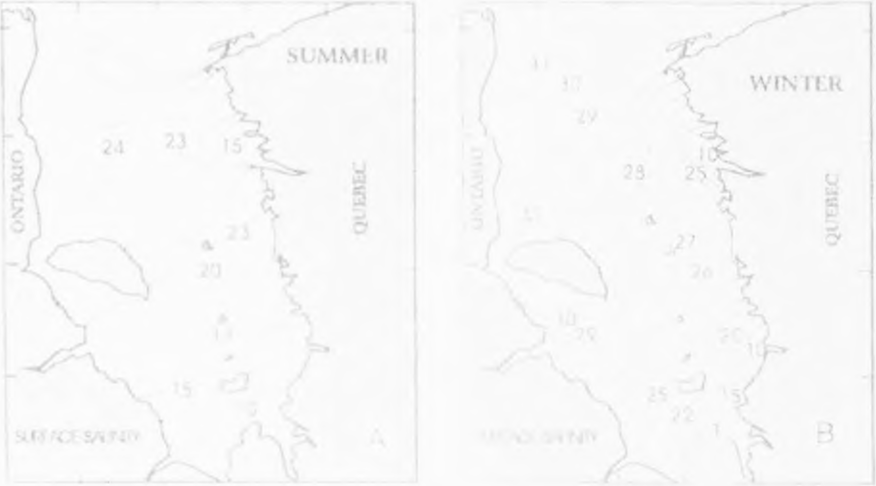
Figure 5-11. **Surface salinities in summer (A) and winter (B) in James Bay (adapted from Ingram and Prinsenberg 1998).**

Under the ice, the surface salinity pattern in James Bay resembles that in the summer but with higher values due to salt rejection due to ice formation and decreased runoff (Figure 5-11; Peck 1976; Prinsenberg 1986a). During the winter, surface water enters from Hudson Bay with a salinity of 31 ‰ (‰= psu), is diluted by runoff as it circulates around the bay, and leaves with a salinity of 28 ‰. In winter, the lowest offshore surface salinity values are still found off the major river systems. In late spring and early summer, the surface water temperature distribution is patchy, with pockets of warm water where ice cover has dissipated and water temperatures near freezing where it has not (Barber 1967).

Extensive freshwater plumes with steep surface salinity gradients are observed off river mouths in Hudson Bay and James Bay year-round (Figure 5-11; Prinsenberg and Freeman 1986). There is considerable variation in these gradients depending upon the runoff volume (Ingram et al. 1986) and other factors such as ice cover (Ingram 1981, 1982) and the tides (Baker 1989; Lawrence 1996). The expansion and compression of the estuarine plume with each low and high tide creates an environment of rapid fluctuations in depth, salinity, temperature, and current to which sedentary estuarine biota must be adapted (Baker 1989).

In winter, ice cover inhibits wind-induced mixing, leaving just tidal current mixing, and allows the plumes to spread further and deeper than under the ice-free conditions of summer, despite runoff rates that can be an order of magnitude lower (Ingram 1981, 1982; Freeman et al. 1982; Ingram and Larouche 1987a+b; Lepage and Ingram 1991; Messier and Anctil 1996). The Nastapoka River plume, for example, is about 40 times larger when there is ice cover than when there is not, despite river runoff that is 2.5 times smaller (Messier and Anctil 1996). Tidal dissipation is the main source of plume mixing during the period of ice cover. This mixing is slow under the relatively smooth landfast ice and faster offshore the ice edge under the rougher pack ice or in leads. Some plumes, such as that from the La Grande River, remain coherent up to 100 km from their source and reach widths of 20 to 30 km (Figure 5-12; Messier et al. 1986, 1989). Under the Coriolis force all currents and plumes are deflected to the right causing them to move counterclockwise along the coast.

The effects of high runoff are most pronounced along the south coast of Hudson Bay east of the Nelson River, in eastern James Bay and along the south coast of the Hudson Bay Arc and, perhaps, in Richmond Gulf. While hydroelectric developments on the Churchill/Nelson and Eastmain/La Grande rivers may not be altering the overall runoff, they are changing its timing and spatial distribution. The effects of these developments on the plumes are discussed further in Section 15.1



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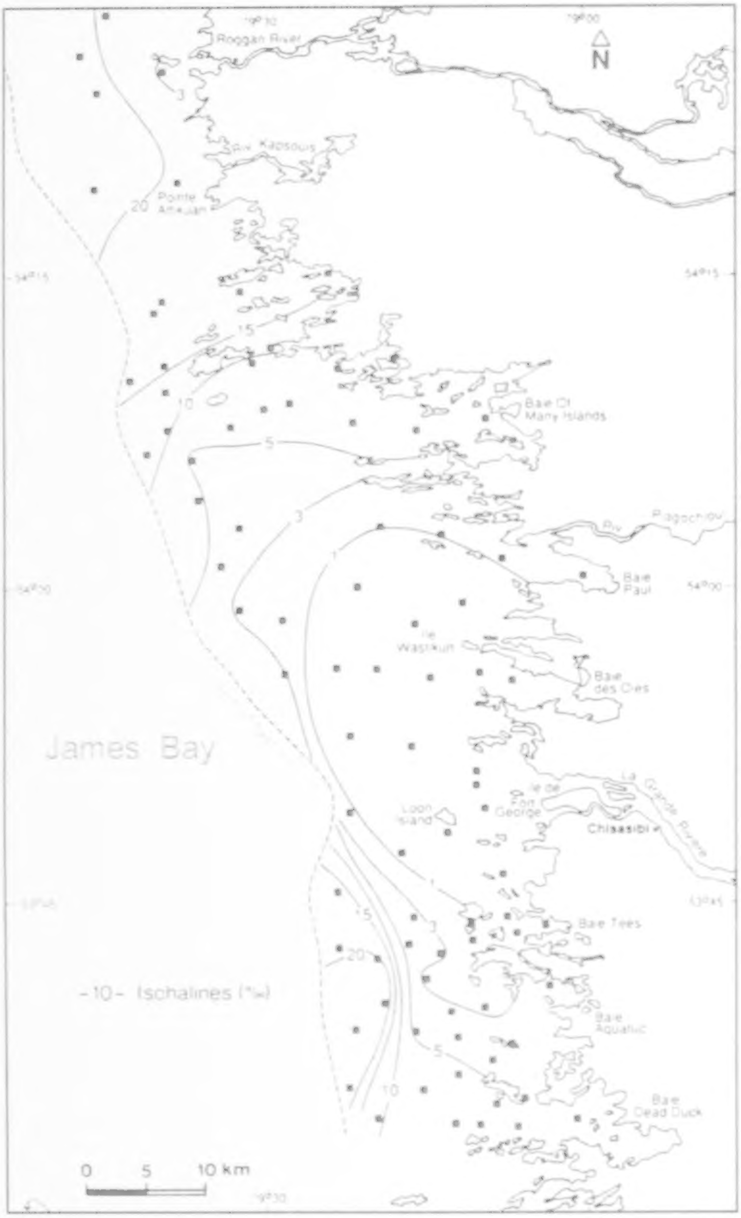

Figure 5-12. **Surface isohalines of La Grande River plume between 20 February and 2 March 1987 (adapted from Messier et al. 1989, p. 280).**

5.5.2 Vertical Profiles

There is a seasonal cycle to the vertical temperature and salinity distributions in Hudson Bay and James Bay (Barber 1967, 1968; El-Sabh and Koutitonsky 1977; Prinsenberg 1982b, 1986a, 1991; Jones and Anderson 1994; Wang et al. 1994a; Ingram and Prinsenberg 1998). In general terms, it involves the dilution of surface waters each spring and summer by fresh water inputs from melting ice and runoff. There is subsequent downward mixing with reduction of runoff and salt rejection from the growing pack ice in fall and winter. Seasonal heating and cooling, tides, and bathymetry contribute to this cycle, which is illustrated in Figure 5-13.

The specifics of this seasonal cycle are not well known, but it likely proceeds as follows (Barber 1967, 1968; El-Sabh and Koutitonsky 1977; Prinsenberg 1982b, 1983, 1986a, 1991; Jones and Anderson 1994; Wang et al. 1994a; Ingram and Prinsenberg 1998). In the spring, runoff and melting ice create a thin layer of low salinity water immediately beneath the ice cover. There is a strong density gradient where this water layer meets the saltier seawater below. This pycnocline limits mixing of the surface and bottom water layers and stabilizes conditions in the water column. As the season progresses, tidal mixing entrains seawater from below and the under-ice surface layer gradually deepens (Figure 5-14 and Figure 5-15; Prinsenberg 1987; Lepage and Ingram 1991). It is mixed by the wind and warmed by the sun once the ice cover disappears but remains relatively shallow (<20 m) through August. The stability of the water column increases through the summer and into September. In late summer and fall, cooler temperatures, lower runoff and stronger winds cause the surface layer to deepen rapidly. When ice begins to form it releases salt into the upper water that further weakens the density gradients and destabilizes the water column. Through the winter the surface layer grows progressively deeper and more saline, with mixing to a depth of 60 to 100 m (Pett and Roff 1982; Prinsenberg 1986a; Jones and Anderson 1994). However, below a depth of 50 m these seasonal changes appear to be small. When the cycle repeats itself in the spring, the weak salinity gradient that separates the surface and bottom water layers is slowly eliminated by vertical diffusion (Prinsenberg 1986a).

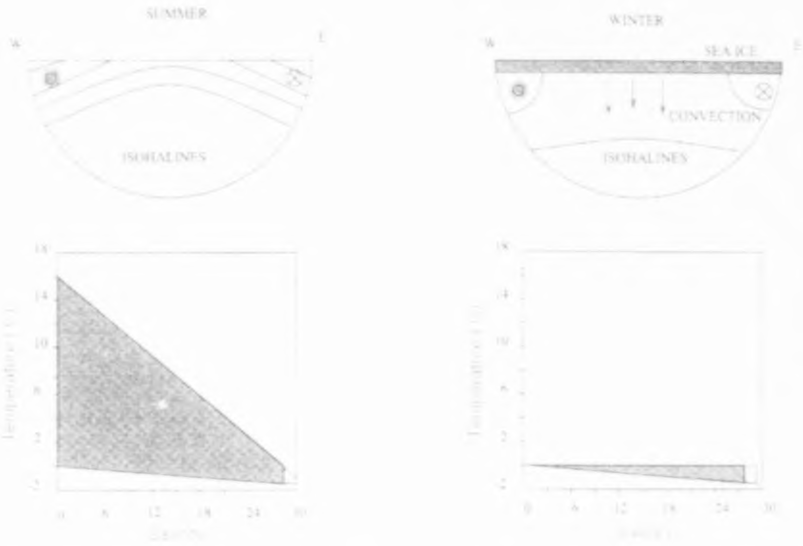

Figure 5-13. Schematic diagram of seasonal differences in the temperature-salinity relations in Hudson Bay (adapted from Ingram and Prinsenberg 1998). Similar current directions are indicated; however, surface flows are stronger in summer than winter. Summer stratification is characterized by a warm and fresher shallow upper layer.

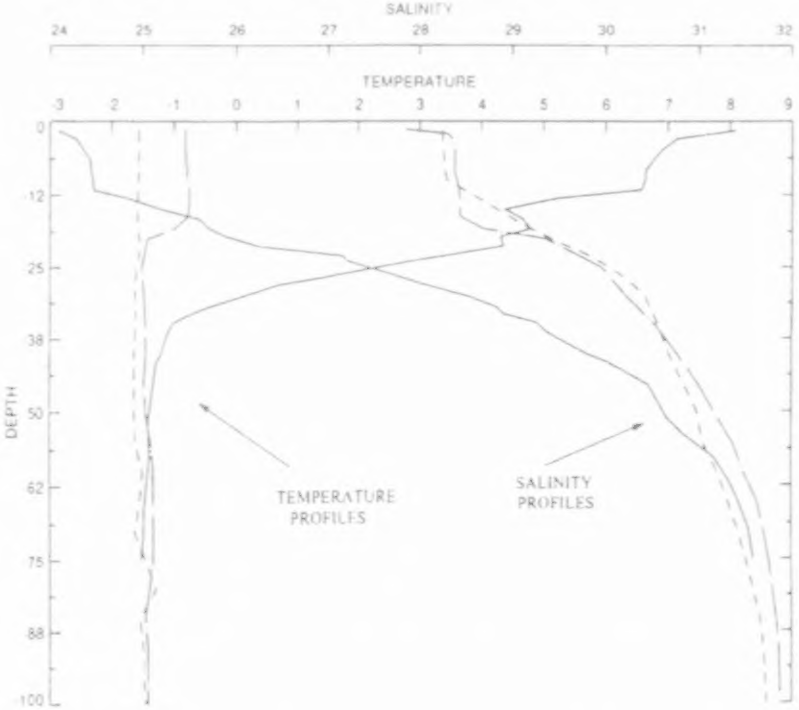

Figure 5-14. Representative vertical profiles of temperature and salinity in southeastern Hudson Bay at various times of the year (different years); April 15, 1982 (dashed line), May 16, 1982 (dashed-dotted line), August 15, 1976 (solid line) (from Ingram and Prinsenberg 1998, p. 851).

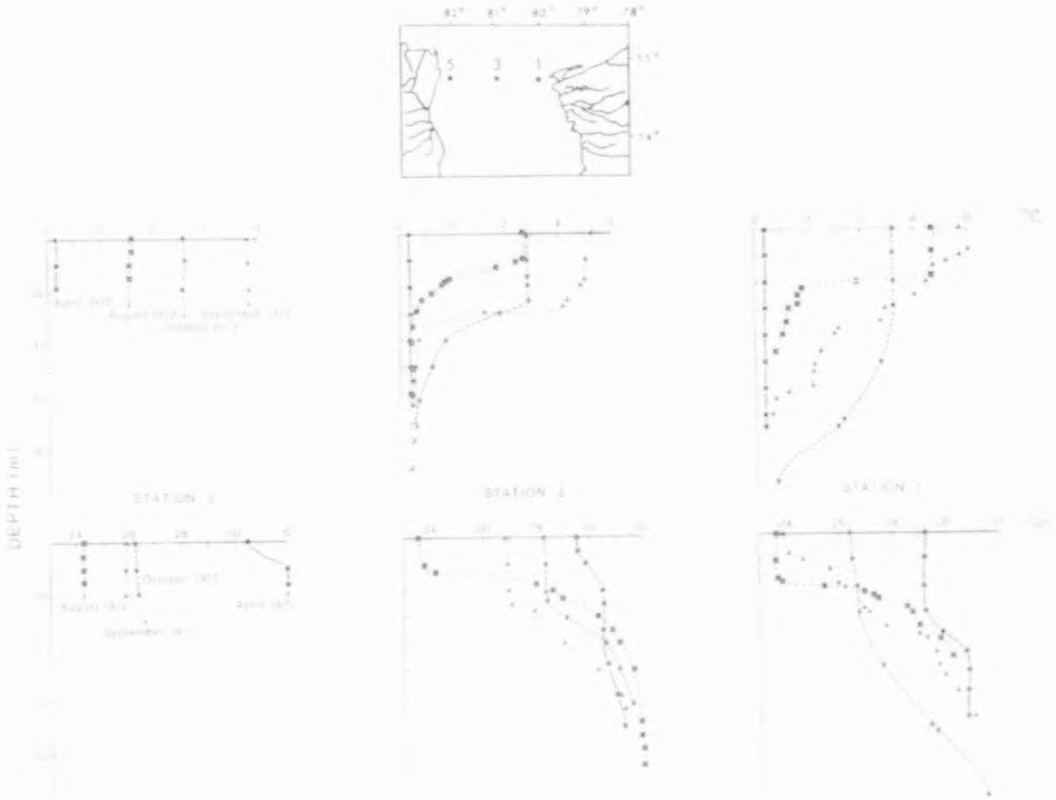

Figure 5-15. **Seasonal vertical profiles of temperature (top) and salinity (bottom) at three oceanographic stations across the entrance of James Bay (see inset) (adapted from El-Sabh and Koutitonsky 1977).**

During the summer months there is a strong pycnocline at 15 to 25 m that effectively prevents vertical exchange between surface and deep waters of Hudson Bay (Anderson and Roff 1980a; Prinsenberg 1986a). This strong vertical stratification is characteristic of Hudson Bay waters in summer. The water becomes progressively colder and more saline with depth, approaching the same deep water type at about 100 m where the mean temperature is less than -1.4°C and salinity greater than 33 ‰ (‰=psu) (Figure 5-16; Hachey 1933; Barber and Glennie 1964; Barber 1967, 1968; Pelletier et al. 1968; Anderson and Roff 1980a; Prinsenberg 1986a; Drinkwater et al. 1991; Jones and Anderson 1994; Simard et al. 1996). The deep water layer in James Bay is subject to considerable seasonal and interannual variation in temperature and salinity, due in part to the relative shallowness of the bay (El-Sabh and Koutitonsky 1977). Limited sampling suggests that the deep water in Richmond Gulf may be less saline than that found elsewhere in the region (27 ‰ at 90 m; Rochet and Grainger 1988). Mixing of water below the pycnocline is much slower than that above, with a turnover time of 3 to 14 years—longest in the deeper water of central Hudson Bay (Barber 1967; Pett and Roff 1982; Roff and Legendre 1986). Below 130 m—the sill depth between Foxe Basin and Hudson Strait, the Hudson Bay bottom water receives higher salinity overflow from Foxe Basin (Jones and Anderson 1994).

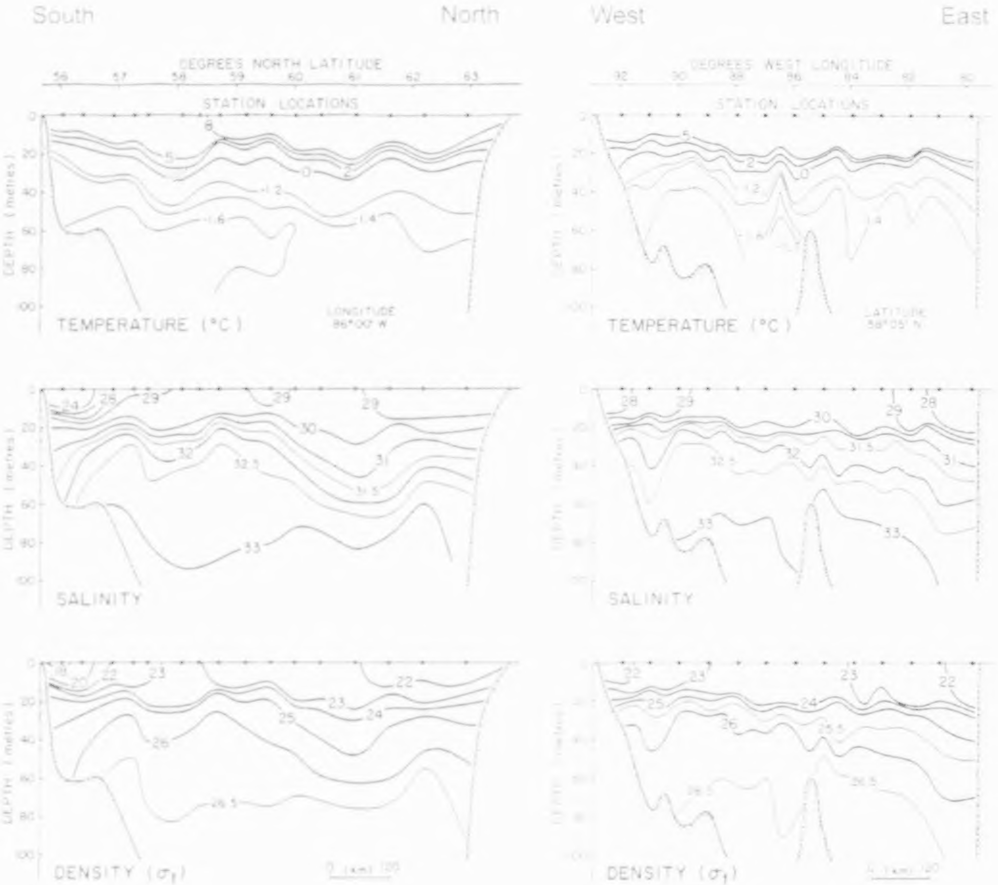

Figure 5-16. **South to north (86°00' W) and west to east (58°55'N) temperature, salinity and density sections from Hudson Bay during the summer of 1975 (from Prinsenberg 1986a, p. 166 and 168).**

Depth and strength of the pycnocline change with the seasons (Prinsenberg 1986a). Profile data from the centre of Hudson Bay show a gradual deepening of the pyncoline as the summer season progresses (Figure 5-17). On 4 August 1975, after the large freshwater input of the ice melt and runoff and during peak solar heating, the pycnoline was observed at 13 m--above that the water was relatively warm and dilute. As summer progressed the pycnocline deepened in response to increasing wind stress and decreasing inputs of heat and runoff. By 28 September it was at 28 m, above which the water was very well mixed. While surface temperature decreased over the summer, the surface layer heat content actually increased, and the highest surface salinity appeared to occur in mid-summer. Changes to the vertical profiles during the rest of the year in Hudson Bay have not been well documented. Data from a year-round monitoring site for temperature and salinity at depths of 18.5, 53.5, and 93.5 m northwest of Churchill show that the pycnocline does deepen due to the fall cooling and salt rejection from the growing pack ice throughout the winter and can reach a depth of 95 m (Figure 5-18).

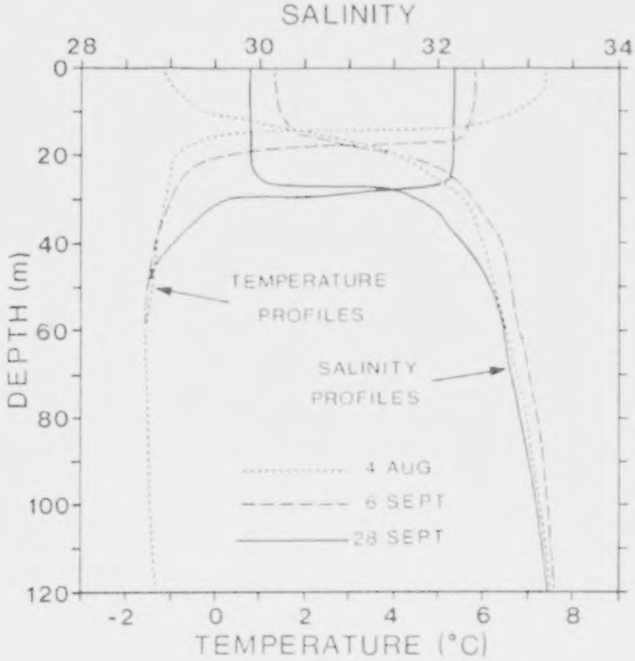

Figure 5-17. Profile data from the center of Hudson Bay (1975) (from Prinsenberg 1986a, p. 173).

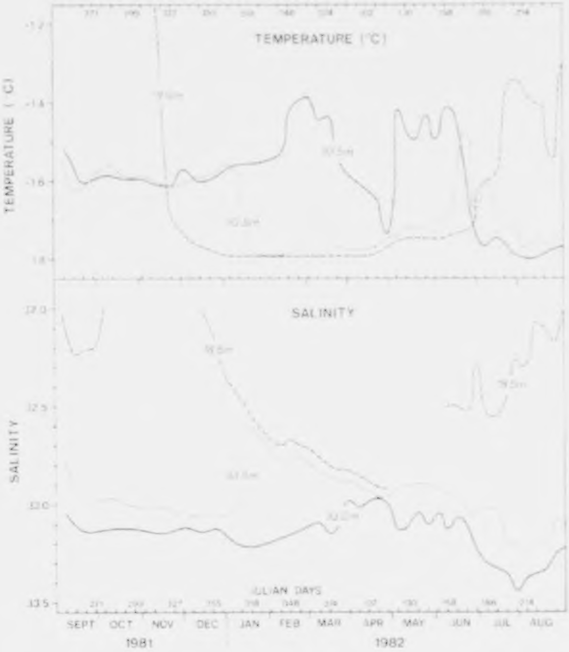

Figure 5-18. Weekly averaged temperature and salinity values as measured by current meters moored 150 km northeast of Churchill at 18.5 m, 53.5 m, and 93.5 m depths (from Prinsenberg 1986a, p. 174).

Summer and winter measurements have been taken across northern and central James Bay (Figure 5-19 and Figure 5-20). They reveal seasonal conditions that are similar to those described above but modified by bottom topography and runoff. Strong vertical density stratification is characteristic of the water column in summer. Depending upon the date of observation and on weather and bottom conditions, there is a well-defined surface layer that ranges in depth from 15 to 30 m (e.g., Barber and Glennie 1964; Barber 1967, 1972; Prinsenberg 1976; El-Sabh and Koutitonsky 1977; Rochet and Grainger 1988). It is separated from the deep-water layer by a pycnocline that is weaker along the west coast of the bay, where there is greater tidal mixing over the shallow topography and less runoff (El-Sabh and Koutitonsky 1977; Prinsenberg 1986a). In March, the waters of northwestern James Bay are relatively saline (>30 ‰; ‰=psu) and unstratified, while those of northeastern James Bay are less saline (about 27-31 ‰) and in some areas show a halocline (Peck 1976). Across central James Bay the salinities decrease progressively from over 30 ‰ along the west coast to less than 27 ‰ along the east coast, with little vertical stratification apparent. The salinity profile changes as a result of winter mixing and could give salinities close to 33 in near surface waters (Prinsenberg 1988b).

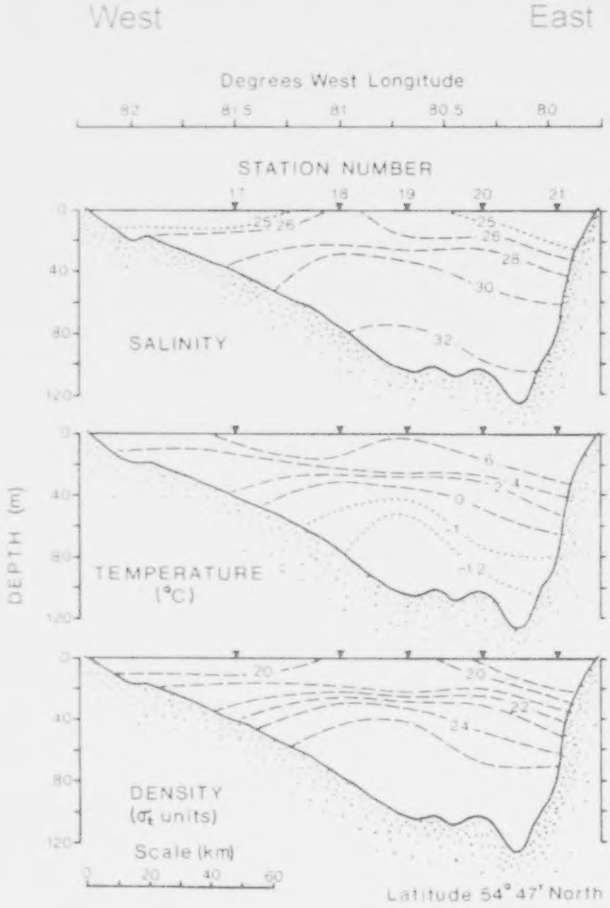

Figure 5-19. **Salinity, temperature, and density sections from the entrance of James Bay along 54°47'N latitude on September 16, 1975 (adapted from Prinsenberg 1986a, p. 170).**

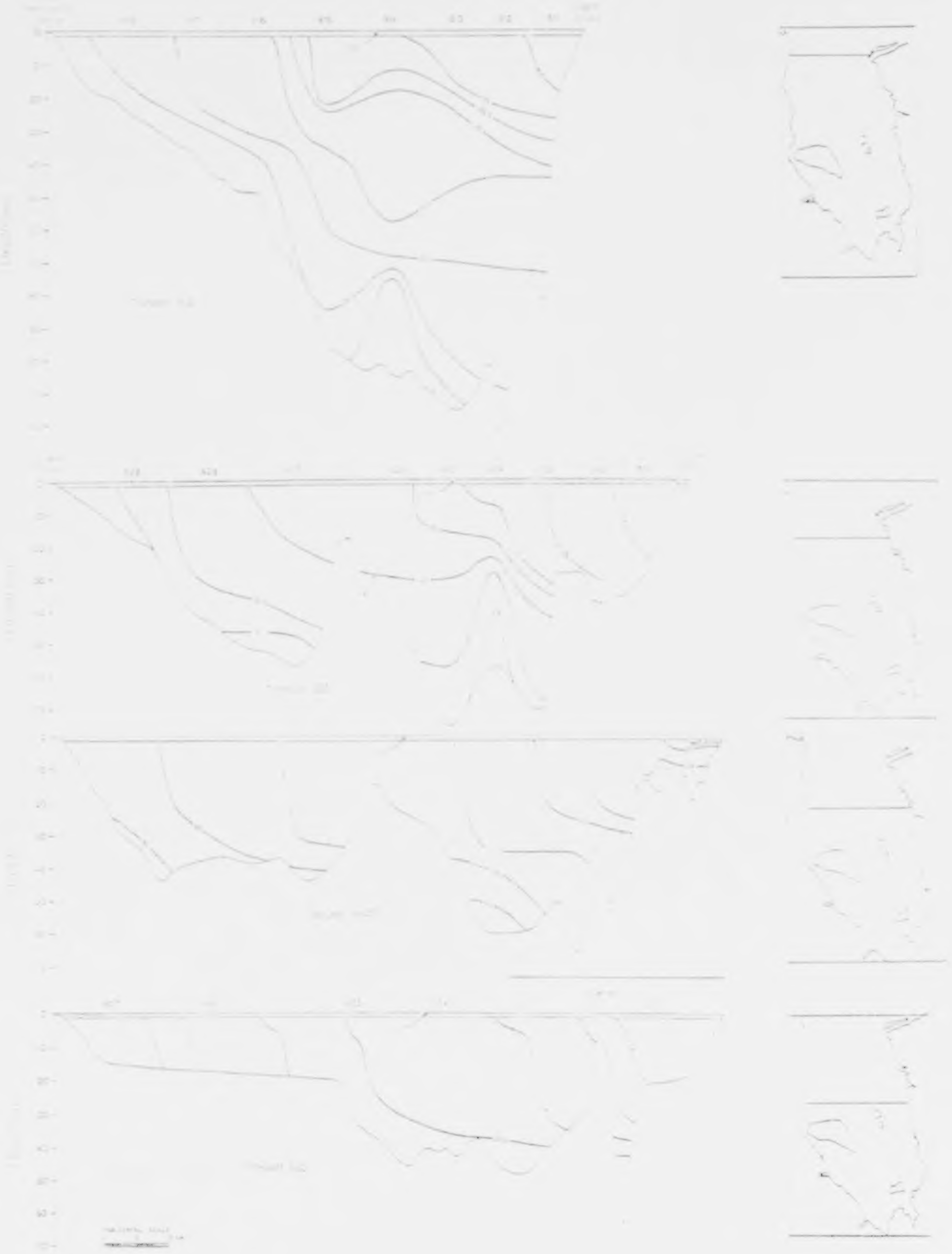

Figure 5-20. **Vertical salinity transects across northern and central James Bay in March 1976 (adapted from Peck 1976, pages 136-139).**

Vertical stratification in the vicinity of the large river plumes varies seasonally and with distance from the river mouth (Legendre et al. 1981; Ingram and Larouche 1987a+b; Ingram et al. 1989; Lepage and Ingram 1991). It is directly related to the runoff volume and inversely related to the tidal kinetic energy (Freeman et el. 1982). The vertical temperature and salinity gradients weaken with increasing distance from the river mouth. This weakening is most pronounced when wind mixing is greatest, during the open water period and in winter outside the fast ice.

Fortnightly tidal variations can have a greater effect on vertical mixing and plume dynamics than changes in runoff (Lepage and Ingram 1986; Messier et al. 1989). This is particularly apparent in Rupert Bay, where the tidal amplitude to water depth ratio is large (0.625) and intense mixing in the lower two-thirds of the estuary causes vertically homogeneous conditions to prevail (Veilleux et al. 1992). The Nelson estuary is also subject to intense tidal mixing such that its water column is vertically homogenous except in the deep central channel (Baker 1989; Baker et al. 1993). The La Grande and Grande rivière de la Baleine estuaries are less affected by tidal mixing and better stratified.

Under the landfast ice, the upper 10 m of the water column in the area of the Grande rivière de la Baleine plume is highly stratified (Figure 5-21; Ingram and Larouche 1987b; Lepage and Ingram 1991). With the onset of ice breakup these salinity gradients are strengthened by the addition of a 2 m layer of fresh meltwater and runoff between the ice and more saline seawater. These stratified conditions persist, with a strong pycnocline between 2 and 4 m depth, until the ice has decayed sufficiently to allow movement of the flows and increase turbulent mixing by the tides and winds. This mixing destroys the shallow pycnocline and collapses the river plume to an area comparable to its open water dimensions. Strong vertical stratification continues to prevail under open water conditions in the reduced area of the plume.

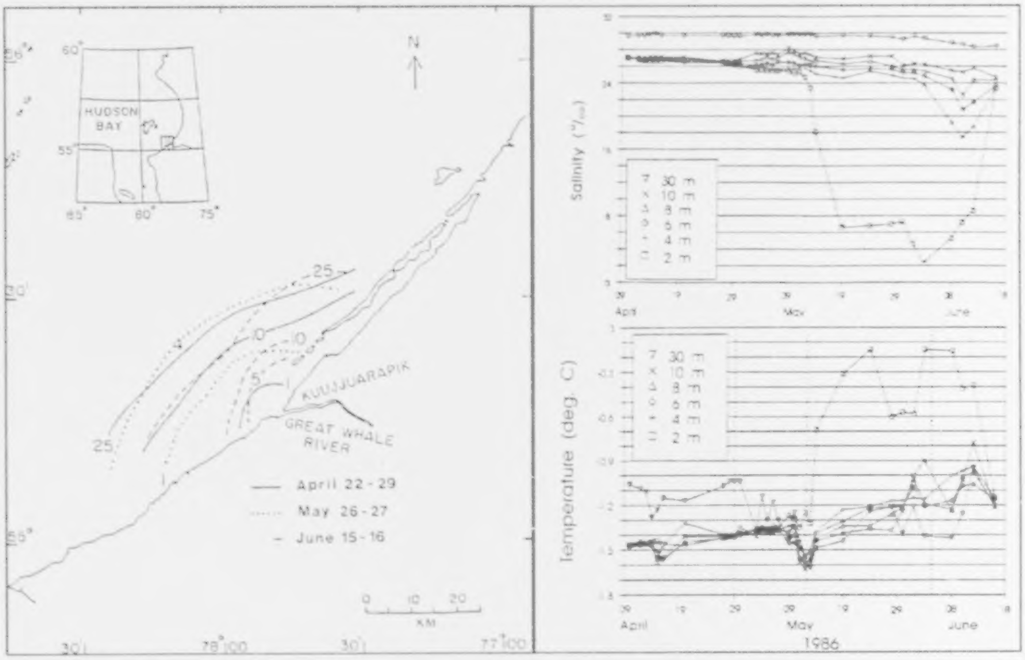

Figure 5-21. **Surface isohalines and salinity and termperature profiles offshore Grande rivière de la Baleine in the spring of 1986 (adapted from Lepage and Ingram 1991, p. 12,714-5).**

The strong pycnoclines in summer, and under the ice near river mouths, slow vertical mixing between surface and deep water layers (Hachey 1933, 1954; Barber 1967, 1968; Roff and Legendre 1986). This vertical stability of the water column is a key factor limiting the concentrations of nutrients that are available to phytoplankton in the surface waters of Hudson Bay during the summer, particularly nitrates (Harvey et al. 1997; Figure 5-22). The historical presence of a large population of bowhead (Ross 1974; Reeves et al. 1983) strongly suggests that there is an area of high productivity and therefore vertical mixing in northwestern Hudson Bay. However, its existence has not been proven.

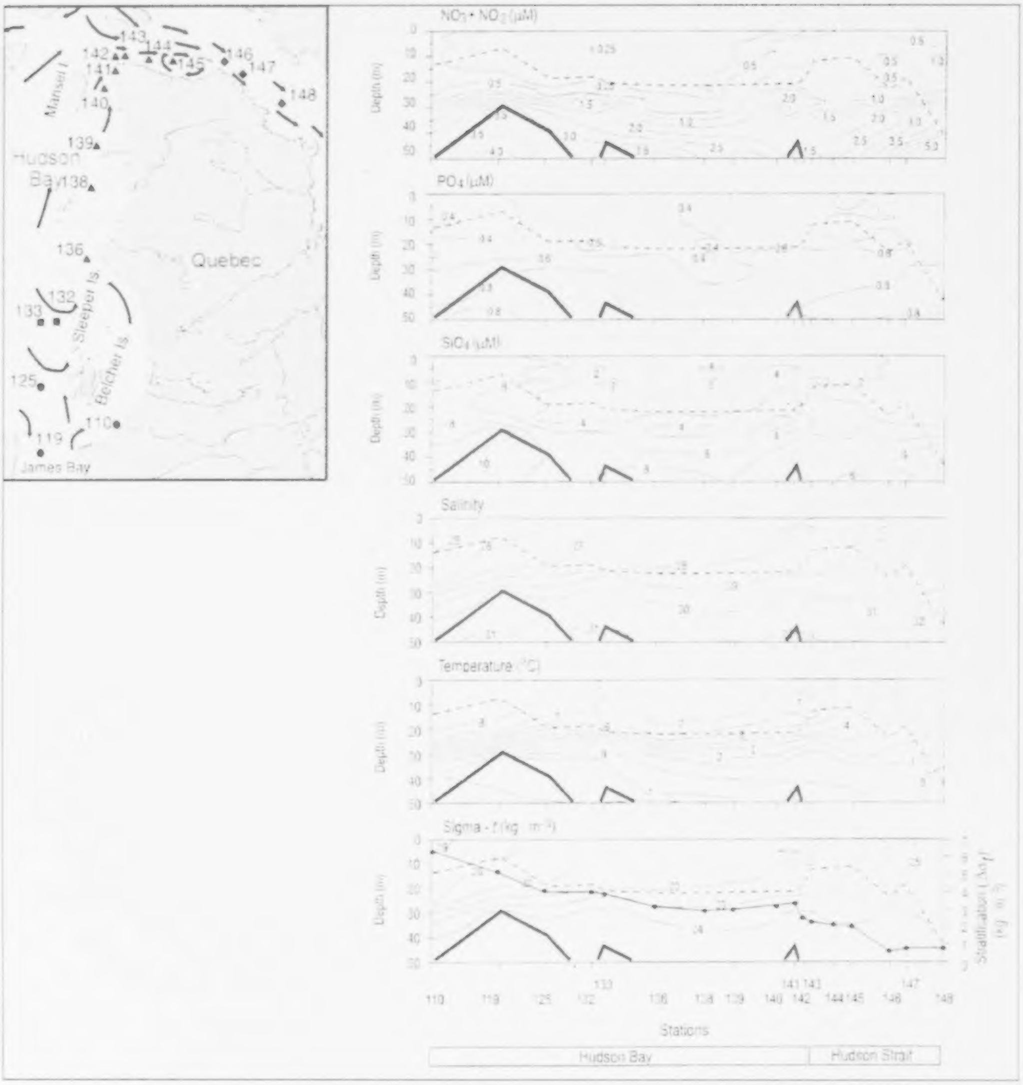

Figure 5-22. Horizontal and vertical distribution of nitrates, phosphates, and silicates in relation to salinity, temperature, and density (σ_t) in the upper 50 m of the water column along a sampling transect in Hudson Bay and Hudson Strait in September 1993 (adapted from Harvey et al. 1997). Also shown are: the depth of the mixed layer (----), which was defined as the depth where the temperature was 1°C less than at the surface; the lower depth limit of the pycnocline (—); and an index of vertical stratification (•—•), which was defined as the difference in density between the bottom and surface layers ($\Delta\sigma_t$). The map symbols indicate distinct phytoplankton assemblages that were identified by cluster analysis (• group A; ▪ group B, ▴ group C, ♦ group D).

Prinsenberg (1991) summarized the importance of the vertical stability of the water column on the biological production as follows:

> *"The vertical stability of the water column is important in determining the magnitude of the vertical nutrient flux required for sustaining surface layer ice algae and phytoplankton spring blooms. Vertical nutrient fluxes are proportional to turbulent current energy and inversely proportional to the density stratification. High production of ice algae and phytoplankton only occur in stable stratification for a short period as nutrients are quickly depleted. Sustained production requires a constant or intermittent nutrient flux without increasing the mixed layer depths beyond the euphotic zone for too long (Gosselin et al. 1985). In the plumes studied in the Hudson and James bays, high biological activity occurs in areas where the vertical nutrient flux is maintained intermittently by tidal mixing at the time when tidal currents reach their maximum amplitude (Gosselin et al. 1985)."*

5.6 WATER CLARITY AND QUALITY

Water clarity as measured by Secchi disk depth during the navigation period in 1959 and 1961, is shown in Figure 5-23. Secchi values ranged from 1.2 m at the head of James Bay to 10 m at the mouth, with a sharp increase in Hudson Bay (Barber 1967; Kranck and Ruffman 1982). The water in Hudson Bay is relatively clear. In August-September 1975, Secchi disk measurements of surface water clarity in the bay averaged 18.2 m offshore and were generally 11-12 m inshore (Anderson and Roff 1980b). Clear photographs of bottom sediments and biota in Barber (1968), Grainger (1968), and Barber et al. (1981) also demonstrate the clarity of some deep bottom waters. In the southern and western areas of James Bay, which are shallow and receive a great deal of sediment laden runoff, the water clarity is low relative to other parts of the marine ecosystem and to other Arctic marine regions generally. There is a progressive increase in water clarity moving northward and also a general increase in water clarity moving offshore.

Clarity of the surface water depends on many factors, particularly those that affect sediment inputs and phytoplankton production, and will vary with location and season. Inshore water clarity is likely least during periods of high runoff, strong onshore winds, and peak primary productivity. Bank erosion during periods of high runoff and from new diversion channels contributes large quantities of sediment to the James Bay marine region (Ingram et al. 1986).

In September 1974, water at the mouth of the La Grande River was turbid, with Secchi depths ranging from <1 m in the river mouth to 2.6 m in the estuary (Grainger and McSween 1976). At the river mouth 1% of the light incident at the surface penetrated less than 2 m into the water, whereas about 8 km offshore it penetrated 7 m. In September 1976, Secchi disk readings at Manitounuk Sound decreased from 10.8 m at the mouth, to 5.9 m at the head of the sound (Legendre and Simard 1979). Water in the Belcher Islands area is clear and appears to be relatively free of suspended sediments. Grainger (1982) estimated that 1% of the surface illumination reached depths of 26 to 44 m during the summers of 1958-59.

During the open water season, high turbidity prevails in Rupert Bay, with a pronounced streakiness in the flow direction and stable fronts at the boundaries of the river plumes (d'Anglejan 1980). In July 1976, suspended sediments averaged 50 $mg{\cdot}L^{-1}$ throughout the water column, with values as high as 200 $mg{\cdot}L^{-1}$ at some stations, and near-bottom levels that may be much higher. During the period of ice cover the suspended sediments were much lower, averaging <10 $mg{\cdot}L^{-1}$, in March 1977. Because of the large number of islands and turbid waters, Rupert Bay is ideal for flow visualization in a natural setting (Ingram and Chu 1987). Turbidity plumes also show clearly the reversing tidal currents in Akimiski Strait (Martini and Grinham 1984).

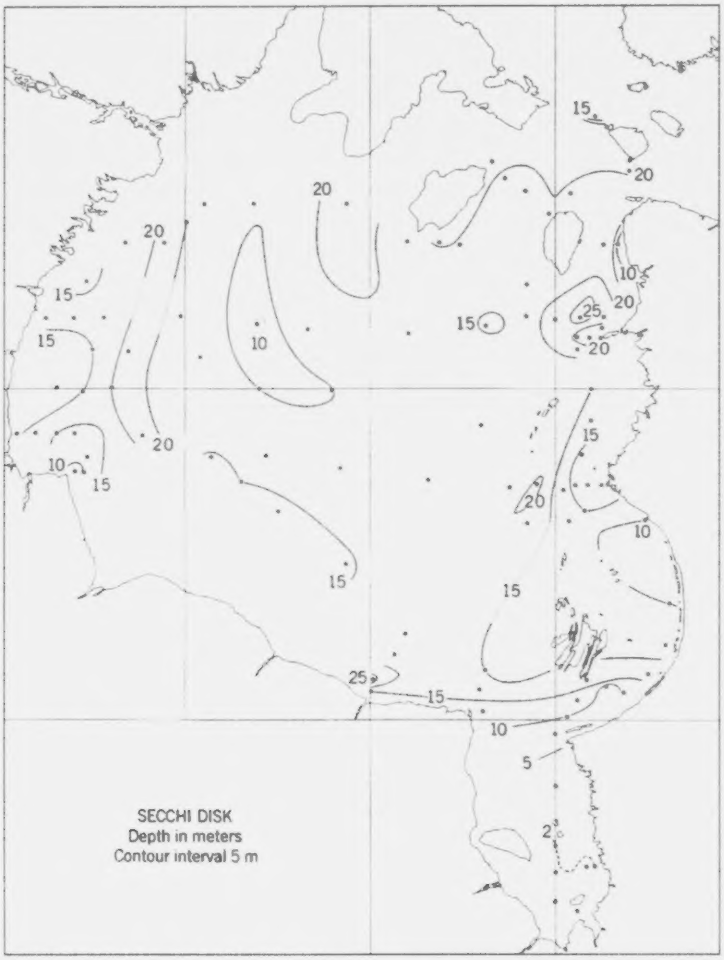

Figure 5-23. **Water clarity in Hudson Bay and James Bay based on Secchi disk observations taken during the navigation period in 1959 and 1961 (from Barber 1972, p. 42). Dots indicate measurement locations, the dashed contour line is in addition to the regular contour interval, and dotted contours indicate a doubtful interpretation.**

5.7 BIOLOGICAL PRODUCTIVITY

Nutrient chemistry, biomass, and productivity of the Hudson Bay marine ecosystem are not well-documented. Anderson and Roff (1980a) conducted the only bay-wide survey of pelagic biomass and it only covered the ice-free summer months in a semi-synoptic survey. Shallow marine waters can be biologically productive if their surface waters receive nutrients from the seafloor. This does not appear to be the case with Hudson Bay, which has a larger area of shallow water than the Gulf of St. Lawrence and Grand Banks combined (780,000 cf. 519,000 km^2 less than 200 m; Pilson and Seitzinger 1996). Several factors, particularly the strong density stratification and relatively low nutrient concentrations in surface waters, suggest that the area is unproductive. Based on extremely limited data, the average annual productivity appears to be low and comparable to that of other seasonally ice-free Arctic marine waters (Roff and Legendre 1986). It appears to be greatest in coastal waters, particularly at embayments and estuaries, and near islands where there is periodic entrainment or upwelling of deeper, nutrient-rich water (Anderson and Roff 1980a; Legendre et al. 1982; Percy

1992). However, the likelihood that maximum primary production occurs in late spring has yet to be measured (Dunbar 1982), and the historical presence of many bowhead and beluga whales suggest that production in some areas may be greater than expected.

The structure of the food web in the Hudson Bay marine ecosystem is not well known, nor is the flow of energy through that web. Inuit and Cree have identified some of the species' interrelationships, based on their observations of predation and stomach contents (Figure 5-24); scientific studies have yet to provide a broad overview of this food web and its energy flow.

5.7.1 Plants

Phytoplankton, ice algae, benthic algae and benthic macrophytes contribute to primary production in the marine ecosystem. Their contributions are difficult to measure. One of the main obstacles to determining the annual primary production is the difficulty of sampling at breakup when the main phytoplankton bloom likely occurs.

Incomplete vertical mixing and the resultant low regeneration rates of nutrients, particularly nitrogen, appear to limit primary production in Hudson Bay (Dunbar 1970; Pett and Roff 1982; Drinkwater and Jones 1987). Deep water mixing and freshwater runoff are important sources of nitrate and total nitrogen, with atmospheric deposition accounting for about 10% of the inputs (Pett and Roff 1982; Roff and Legendre 1986). Nitrate and phosphate levels in surface waters are very low during the summer (see also Grainger and McSween 1976) and relatively high in sea ice and snow cover. Melting snow and ice cover may be an important nutrient source during the spring phytoplankton bloom (Freeman et al. 1982).

Freshwater runoff affects the primary productivity negatively by increasing vertical stability of the water column, and positively through nutrient additions--either direct or due to deep-water entrainment (Anderson and Roff 1980a; Pett and Roff 1982). While river runoff carries large quantities of carbon and nutrients into the marine ecosystem, particularly during ice-breakup, the river waters are less concentrated in nutrients than Hudson Bay coastal waters (Grainger and McSween 1976; Roff et al. 1980; Freeman et al. 1982; SEBJ 1990; Schneider-Vieira et al. 1993; Hudon et al. 1996; Figure 5-25). Overall, the concentration of dissolved organic carbon in waters of rivers flowing through tundra to Hudson Bay is about half that of rivers flowing through forested basins to the Gulf of St. Lawrence (Hudon et al. 1996). The annual exportation of particulate inorganic matter (PIM), particulate organic matter (POM), and dissolved organic carbon (DOC) to Hudson Bay from the Great Whale River were estimated at 135,000, 21,000, and 90,000 t, respectively in 1990-91. Concentrations were positively related to discharge. Of three size-fractions of particulate organic matter examined, the finest (0.7-53 µm) exhibited the highest heterotrophic activity, the lowest C:N ratio, and the highest chlorophyll ***a*** concentration (1 $\mu g \cdot L^{-1}$) during the summer. Primary production by phytoplankton in the estuaries of Hudson Bay may be limited by low nutrient concentrations and turbulence, which mixes cells out of the photic zone (Schneider-Vieira et al. 1993).

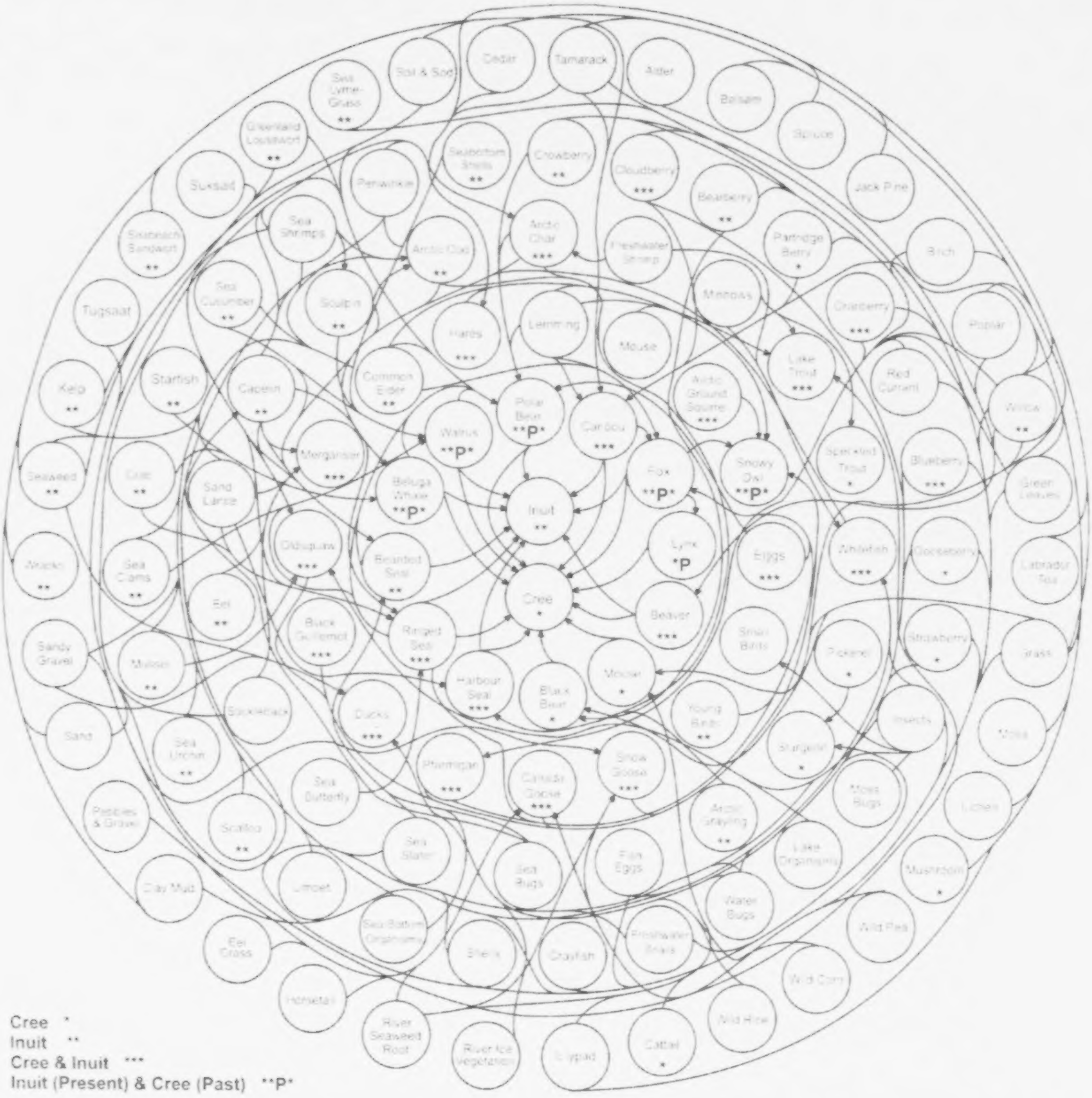

Figure 5-24. Traditional knowledge of the structure of the Hudson Bay food web (from McDonald et al. 1997, p. 20).

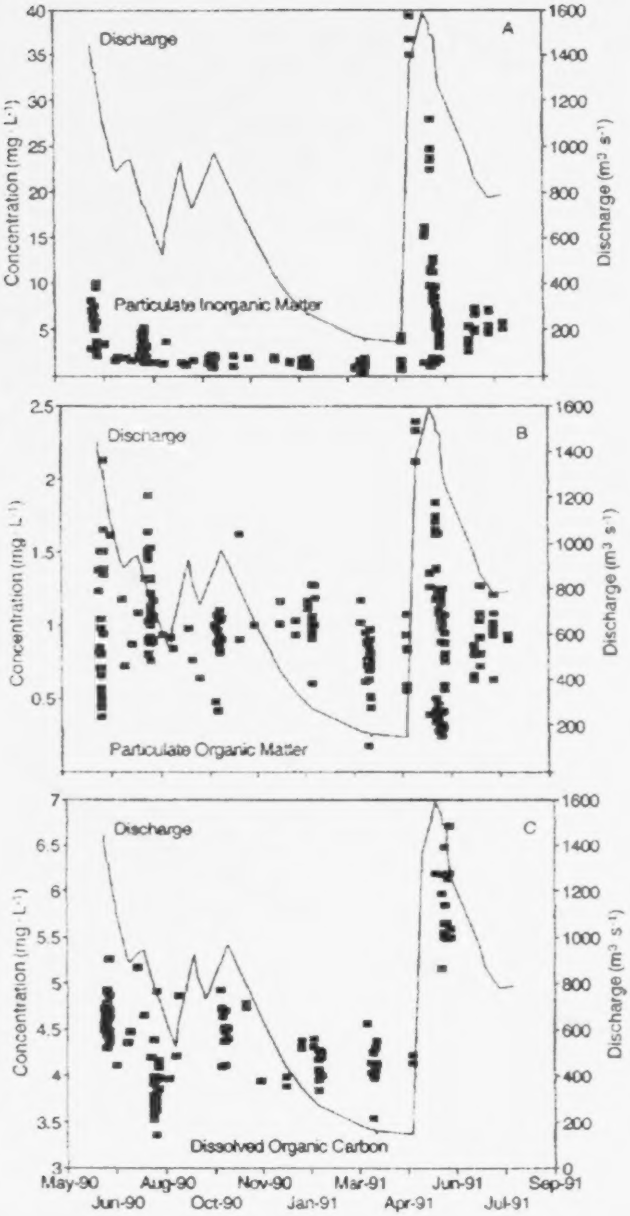

Figure 5-25. Seasonal variations in the concentrations of (A) inorganic and (B) organic particulates, (C) dissolved organic carbon, and runoff discharge from Grande rivière de la Baleine (Great Whale River) (From Hudon et al. 1996, p. 1517).

During the summer, primary productivity in the Hudson Bay marine ecosystem appears to be greater inshore than offshore (Figure 5-26). In August and September 1975, the primary production by phytoplankton southwest of the Belchers was similar to that observed in coastal areas of Hudson Bay (Anderson and Roff 1980a). The mean concentrations of particulate organic carbon, chlorophyll ***a***, and ATP were generally 2 to 3 times higher in these inshore areas than in offshore areas of Hudson Bay (Anderson 1979; Anderson and Roff 1980a). High chlorophyll ***a*** levels were found west of the Belcher and Sleeper archipelagos and near the entrance to James Bay, with maximum concentrations generally at or above the pycnocline (Anderson and Roff 1980b). Offshore in Hudson Bay the maximum summer chlorophyll concentrations were found below the pycnocline where nutrient concentrations are higher and the clear waters allow sufficient light penetration for photosynthesis (Figure 5-27; Anderson 1979; Anderson and Roff 1980b; Roff and Legendre 1986). This is one of the most northerly reports of a subsurface maximum and one of the most highly developed. It may contribute significantly to the annual production of Hudson Bay. Harvey et al. (1997) also found a well-developed subsurface chlorophyll ***a*** maximum at stations in northeastern Hudson Bay and western Hudson Strait (Figure 5-22; group C).

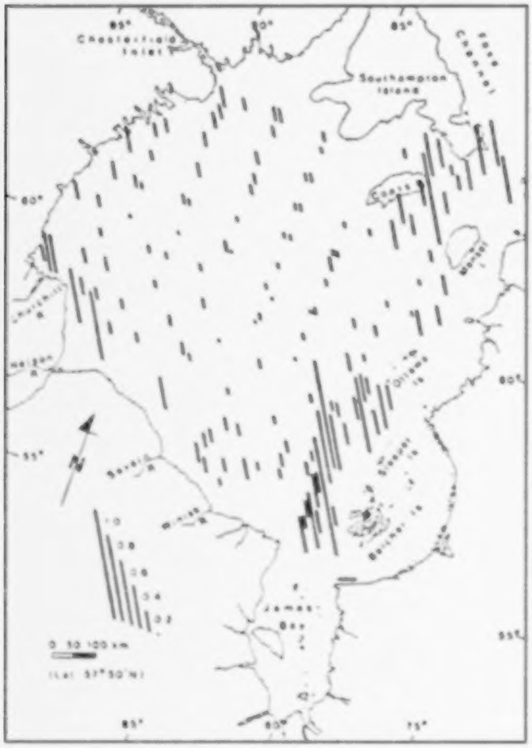

Figure 5-26. **Surface chlorophyll *a* (mg·m^{-3}) distribution in Hudson Bay, August-September, 1975. Station location is base of bar (from Anderson and Roff 1980a, p. 2247).**

In summer, most primary productivity occurs in the upper 10 m of the water column, at or above the pycnocline (Legendre and Simard 1979; Anderson and Roff 1980b; Grainger 1982). At the Belcher Islands in the summer of 1959, the maximum-recorded rate of primary production was about 3 mg C·m^{-3}·h^{-1} (Figure 5-28). This was closely similar to the rates measured by Legendre and Simard (1979) in Manitounuk Sound (about 2.5 mg C·m^{-3}·h^{-1}), and notably low in the range of recorded marine values (Grainger 1982). These hourly rates translate to an annual primary production rate of about 35 g C·m^{-2}·a^{-1}, not including the main spring diatom bloom or ice algal production (Roff and Legendre 1986). In Manitounuk Sound, the summer blooms of phytoplankton occurred following stabilization of a previously unstabilized water column (Legendre et al. 1982).

Primary production under ice-covered conditions is not well known, but there is probably a well-developed microalgal community at the bottom of the ice in spring throughout most of Hudson Bay and James Bay (Freeman et al. 1982). The production of sea ice microalgae depends upon the available light energy, fortnightly tidal mixing which replenishes nutrients and removes accumulated algal biomass from the ice/water interface, and the heat flux responsible for the maintenance or destruction of energetic interfaces (e.g., the ice/water ergocline) (Gosselin et al. 1985; 1990; Demers et al. 1989). In southeastern Hudson Bay, production by sea-ice microalgae appears to be nitrogen limited (Maestrini et al. 1986; Demers et al. 1989). The salinity of surface waters underlying the ice is a major determinant of the standing crop and taxonomic composition of the ice algae, both of which are lower near freshwater outflows such as the Grande rivière de la Baleine (Poulin et al. 1983).

In 1982 at Manitounuk Sound, Gosselin et al. (1985) observed the maximum concentrations of ice-algal cells and chlorophyll ***a*** on 7 May at the ice water interface and also in the bottom 20 cm of ice (12 x 10^{8} cells·m^{-2} and 0.85 mg Chl ***a***·m^{-2}). Poulin et al. (1983) sampled the same station in May 1978 and reported similar values.

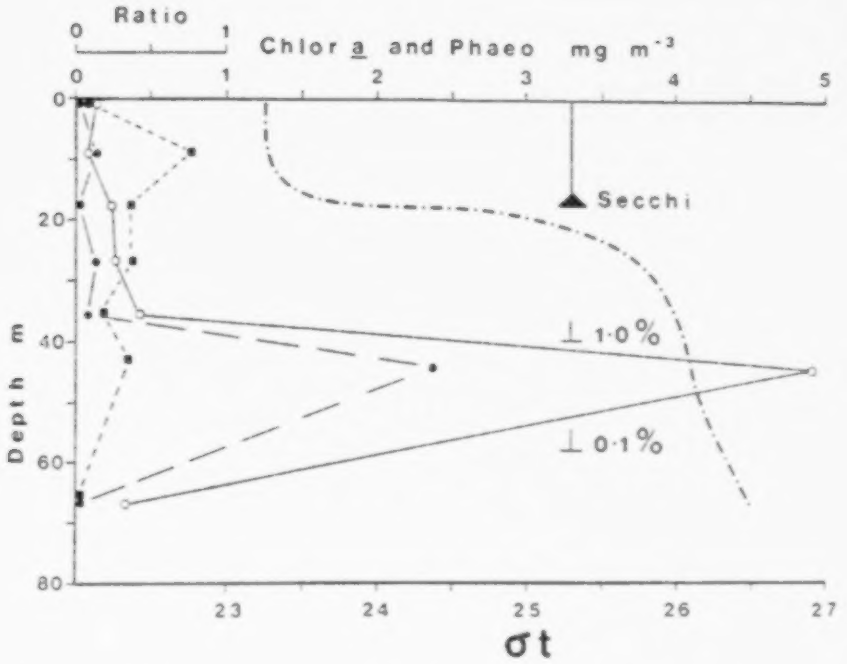

Figure 5-27. Vertical profiles of chlorophyll *a* (—), phaeopigments (•—•), phaeopigment to chlorophyll *a* ratio (▪ – ▪), and density (σ t; • – •) representative of the offshore region of Hudson Bay (from Anderson and Roff 1980b, p. 211). The 1.0 and 0.1% light levels were calculated from Secchi disc readings.

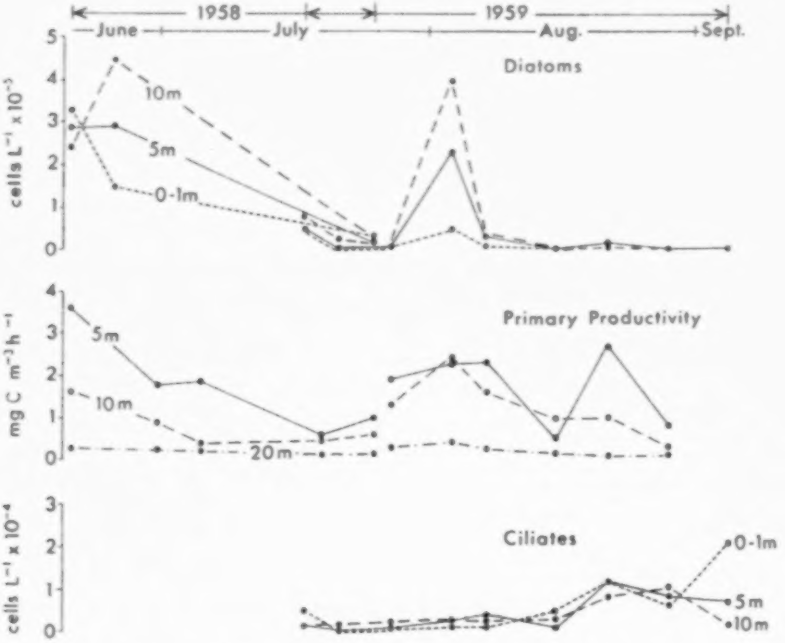

Figure 5-28. Seasonal variations of diatom counts, primary productivity rates, and ciliate counts at selected depths near the Belcher Islands (from Grainger 1982, p. 790).

These chlorophyll concentrations are an order of magnitude lower than many of those reported from other Arctic seas (e.g., Apollonio 1965; Dunbar and Acreman 1980; Hsiao 1980; Grainger and Hsiao 1982). It is not known whether they are representative of southeastern Hudson Bay.

Jones and Anderson (1994) estimated the total biological productivity in the upper 40 m of the Hudson Bay watercolumn to be at least 24 g $C{\cdot}m^{-2}{\cdot}a^{-1}$. Roff and Legendre (1986) estimated that the production of all planktonic and epontic communities in productive inshore areas of Hudson Bay may reach 70 g $C{\cdot}m^{-2}{\cdot}a^{-1}$. These estimates are comparable to those of other Arctic marine waters where primary production estimates range from 12 to 98 g $C{\cdot}m^{-2}{\cdot}a^{-1}$ --based on a 120 day growth season, with the higher values generally observed in the coastal bays and fjords (Subba Rao and Platt 1984).

Little is known of the primary production by benthic algae in this region but in Rupert Bay and Manitounuk Sound, where benthic algae have been studied (Breton-Provencher and Cardinal 1978), the low biomass observed suggests that productivity is also low.

Eelgrass beds in James Bay appear to be productive relative to their surroundings but no data were found on their rate of primary production. Depending on conditions the eelgrass, *Zostera marina*, grows at a density ranging from 88 to 1,761 shoots$\cdot m^{-2}$ and produces a dry biomass of 34 to 472 $g{\cdot}m^{-2}$ (SEBJ 1990). The density and biomass of the beds vary with location and year in response to the effects of waves and currents, ice, turbidity, water temperature, and illumination. While less dense and productive than beds in Alaska, which have densities of 788 to 5,033 plants$\cdot m^{-2}$ and biomasses of 186 to 1,840 g dry weight$\cdot m^{-2}$ (McRoy 1970), the communities do form the base of major food chains in the James Bay marine ecosystem (Curtis 1974/5; Ettinger et al. 1995).

Coastal salt marshes may be very productive relative to other areas of this region (see Section 4-5), but their contribution of food energy to the marine ecosystem is unknown.

5.7.2 Invertebrates

Secondary productivity may be of the same order as seasonally ice-free Arctic marine waters but significantly lower than that of temperate oceans as a consequence of longer generation times in the colder water, particularly offshore where the numbers and biomass are lower (Roff and Legendre 1986). Manitounuk Sound, for example, had an estimated standing biomass of copepod zooplankton of 0.7-0.9 g ash free dry weight$\cdot m^{2}$ and productivity of 80 $kJ{\cdot}m^{-2}{\cdot}a^{-1}$ in summer (Simard pers. comm. in Roff and Legendre 1986). In summer, Rochet and Grainger (1988) found the greatest copepod densities in southeastern Hudson Bay above the pycnocline near shore. Grainger and McSween (1976) found the zooplankton of James Bay to be present in moderate quantity and fairly high diversity for northern waters.

Small concentrations of commercially attractive benthic macroinvertebrate species have been located in the Belchers (Jamieson 1986; Giroux 1989). Individuals of some of these species, such as the green sea urchin *Strongylocentrotus droebachiensis* and blue mussel *Mytilus edulis*, are smaller as a rule than their temperate counterparts (Lubinsky 1980; Jamieson 1986). Test fisheries for invertebrates along the western and northeastern coasts of Hudson Bay have not identiified commercially attractive concentrations of benthic invertebrates (Morin 1991; Doidge 1992b; Doidge and Prefontaine 1997; Stewart 1994).

There are very few data on production by pelagic and benthic invertebrates in the Hudson Bay marine region but what there are suggest low productivity--despite the presence of large numbers of shorebirds and former presence of large numbers of bowhead. The *Calanus* Expedition found a good standing crop of Euphasiids in the Coats Island area but these data were never published (E.H. Grainger, DFO, Ste. Anne-du-Bellevue, pers. comm.). During summer, limited data suggest that the numbers and biomass of metazoan zooplankton in inshore and estuarine areas are similar to temperate oceans, while in offshore areas they are much lower--presumably as a consequence of low primary productivity (Roff and Legendre 1986). The biomass and abundance of total zooplankton along a north-south transect from the mouth of James Bay to Hudson Strait were low in the south (averaging 1.6 g $DM \cdot m^{-2}$ and 9432 $ind \cdot m^{-2}$) and increased sharply at the upper end of the bay and in Hudson Strait (averaging 6.0 g $DM \cdot m^{-2}$ and 40,583 $ind \cdot m^{-2}$) (Harvey et al. 2001).

In James Bay, the maximum diversity of the zoobenthos recorded from a single sampling site by Wacasey (1976) was 35 species, and the maximum biomass was 13 $g \cdot m^{-2}$. This is less than in other areas of the Eastern Arctic, but comparable to known values from bottoms with similar conditions in the southern Beaufort Sea. Along the west coast of James Bay, high densities of the clam *Macoma* and gastropod *Hydrobia* have been observed in sandy, sheltered flats or bays (Martini et al. 1980b). Nearby, coastal areas influenced by river mouths were found to have very low densities of invertebrates.

5.7.3 Vertebrates

As with plants and invertebrates, little is known of vertebrate productivity in the Hudson Bay marine ecosystem. But, species abundance provides indirect evidence for higher productivity in some areas.

Anadromous species excepted, commercially attractive fishes have not been found in sufficient quantity to warrant fishery development (e.g., Hachey 1931; Vladykov 1933; Hunter 1968; Dunbar 1970; M. Allard, Makivik, Corp., Lachine, pers. comm.). This suggests that inshore and estuarine areas may be more productive than offshore areas, and that the offshore areas may be less productive than other oceans at similar latitudes--the extent to which it reflects the difficulty of sampling the deeper offshore waters is unknown.

The numbers of some mammal and bird species have been estimated, but most of them are migratory. The contribution food resources in the waters of James Bay and southeastern Hudson Bay make to their biological productivity is unknown. The seasonal abundance of shorebirds and waterfowl in coastal saltmarsh habitats, and of waterfowl at eelgrass beds, suggests that these may be relatively productive habitats. So too, the historical summer presence of large numbers of belugas in the Churchill, Nelson, Nastapoca, Grande Baleine, and Petite Baleine estuaries; concentrations of walrus at Cape Henrietta Maria and on Coats Island; and bearded seal in the Belchers. The historical presence of a large population of bowhead (Ross 1974; Reeves et al. 1983) strongly suggests that there is an area of high productivity in northwestern Hudson Bay, but its existence has not been proven. The apparent historical rarity of bowhead in James Bay and southeastern Hudson Bay suggests that the production by copepod zooplankton may be insufficient to support them in these areas.

5.8 SUMMARY

The Hudson Bay marine ecosystem consists of two oceanographically distinct marine regions. The water properties of these regions depend mainly on exchanges with Foxe Basin and Hudson Strait and the large freshwater input from both runoff and melting sea ice in the spring and summer. An understanding of their differences is critical to the design and integration of coastal zone management initiatives.

The northern area, or **Hudson Bay marine region**, is characterized by the presence of Arctic marine water and biota, complete winter ice cover and summer clearing, moderate semidiurnal tides of Atlantic origin, a strong summer pycnocline, greater mixing and productivity inshore than offshore, and low biological productivity relative to other oceans at similar latitudes. Hudson Bay lacks the typically subarctic species that are found in Hudson Strait but does support some of the relict warm-water species found in James Bay.

The southern area, or **James Bay marine region**, is closely coupled oceanographically to the Hudson Bay marine region but its waters are typically shallower and more dilute, being modified to a much greater extent by freshwater runoff from the land. Its species composition reflects these Arctic and freshwater influences and it supports a variety of warm-water species that are relicts of an earlier connection with the Atlantic and Pacific oceans. These plants and animals have disjunct distributions and are rare or absent elsewhere in Canada's

Eastern Arctic waters. Southeastern Hudson Bay is included in this region with James Bay largely on the basis of biogeography. Strong density stratification limits mixing and leads to considerable surface warming by insolation in both marine regions.

Because of its remote location and the non-commercial nature of its marine resources, relatively few oceanographic field programs have been undertaken in the Hudson Bay ecosystem, where seasonal ice cover effectively prevents most year-round research and the shallow coastal waters make it very difficult to conduct bay-wide research from a single research platform. Consequently, characteristics of the circulation and water mass are not well known, especially outside the open water period.

In summer, surface water circulates cyclonically (counterclockwise) around Hudson Bay, and the deep water moves in the same general direction but is influenced by bottom topography. Cold, saline Arctic water from Foxe Basin enters Hudson Bay in the northwest via Roes Welcome Sound. As it flows eastward along the southern coast of Hudson Bay some of this water enters James Bay while the remainder is deflected northward to exit northeastward into Hudson Strait. A westward, wind-driven return flow across the top of Hudson Bay has been predicted by modelling studies, and there is a small--perhaps intermittent, intrusion of Atlantic water from Hudson Strait at the northeastern corner of Hudson Bay. Mathematical modelling suggests that the main reasons for this stable cyclonic circulation are the relatively weak coastal currents with limited coastal development to cause mixing, a relatively strong Coriolis effect that stabilizes the flow pattern by turning the freshwater outflow from rivers cyclonically around Hudson Bay, and strong density stratification due to intense freshening in summer. This circulation is maintained by inflow/outflow forcing that likely occurs year round, and reinforced during the open water season by wind and buoyancy forcing. The extreme southerly incursion of Arctic waters creates Arctic oceanographic conditions much further south than elsewhere along the North American continent, and is a key feature of the Hudson Bay marine ecosystem.

There is little Atlantic influence except in terms of the tides which enter Hudson/James Bay twice daily via Hudson Strait. These semidiurnal tides move as a Kelvin wave counterclockwise around the coastline and overshadow other tidal influences. They do not attain the extreme ranges in height found in Hudson Strait. Dangerous storm surges do occur in southern James Bay.

The Hudson Bay marine ecosystem is unusual among the world's oceans in that it is nearly covered by ice in winter and is free of ice in summer. In spring and summer, the cold saline surface water that enters the region is diluted by meltwater and runoff from the land, warmed by the sun, and mixed by the wind as it circulates through Hudson Bay and James Bay. This produces the strong vertical stratification of the water column that is characteristic of the ecosystem in summer, particularly offshore. This stratification slows vertical mixing, thereby limiting nutrient additions to surface waters and biological productivity. In winter, lower runoff, ice cover, and surface cooling weaken the vertical stratification and permit very slow vertical mixing. There is little coastal development or bottom relief to promote mixing or upwelling that might increase the availability of chemical nutrients in the surface waters. Temperature and salinity are relatively stable below a depth of 50 m, but small changes related to the seasonal disappearance of the pycnocline have been observed to 65 m in James Bay and 100 m in Hudson Bay. The water becomes progressively colder and more saline with depth, approaching the same deep water type at about 100 m where the mean temperature is less than -1.4°C and salinity greater than 33 ‰ (‰=psu). The deep water layer in James Bay is subject to considerable seasonal and interannual variation in temperature and salinity, due in part to the relative shallowness of the bay. Seasonal oceanographic variations are not well known. There is no complete set of temperature-salinity transects that covers the entire area in any season, and most sampling has been conducted during the open water season.

The extreme southern presence of nearly complete ice cover with extensive areas of fast ice and polynyas strongly affects this region's physical and biological oceanography, the surrounding land, and human activities. Depending on weather conditions, the timing of freeze-up or breakup may be retarded or advanced by up to a month, but the basic pattern of ice formation remains similar. The reliance of Inuit and coastal Cree on sea ice for travelling and hunting is reflected in their detailed knowledge of its processes, characteristics, and annual cycles. The sea ice determines the ecology of the ice biota and it also influences pelagic systems under the ice and at ice edges. As the interface between air, ice, and water, ice edge habitats are areas of mixing that attract biota to feed. These areas are important sites of energy transfer within the ecosystem.

In winter and early spring the ice floes are kept in constant motion by the wind. Leads develop when the winds blow offshore and are quickly covered by new and young ice. These leads are important habitat for species such as the Hudson Bay eider that overwinter in the region and to migratory birds and mammals that arrive early in the spring. Recurring polynyas are present in the Belchers and near islands along the coast of southeastern Hudson Bay, in Roes Welcome Sound, at the northern tip of Coats Island, near Digges Island, and just off the southwest tip of Akimiski Island. The latter polynya is one of the most southerly in Canadian seas. These openings in the sea ice are vitally important to overwintering species and to early spring migrants. They are often areas of increased biological productivity. Old ice and icebergs are rare in Hudson Bay and rare or absent James Bay.

The importance of sea ice to the Hudson Bay marine ecosystem and its vulnerability to climatic warming have spurred efforts to develop a mathematical model that accurately simulates the region's sea ice dynamics.

The volume of freshwater runoff to this region from the land is very large and has an even greater effect on the oceanography of the James Bay marine region than is seen in the Hudson Bay marine region. It has a strong influence on the timing and pattern of the breakup of ice cover, the surface circulation, water column stability, species distributions, and biological productivity. Summer surface salinity values over most of this region are low relative to other marine regions. Extensive freshwater plumes are observed off its river mouths year-round. They spread further and deeper under the ice than under the ice-free conditions of summer, despite runoff rates that are an order of magnitude lower. The effects of high runoff are most pronounced in eastern James Bay, along the southeastern coast of Hudson Bay and, perhaps, in Richmond Gulf. In southern and western James Bay, which are shallow and receive a great deal of sediment laden runoff, the water clarity is low relative to other parts of the marine ecosystem and to other Arctic marine regions generally.

In summer, there are distinct physical and biological oceanographic differences between inshore and offshore areas of this region. Inshore areas generally have lower water temperatures, salinities, and clarities and higher chlorophyll ***a***, ATP, and pelagic biomass. These differences may be attributable to mixing processes which bring colder, deeper, relatively nutrient-rich water to the surface, and to dilution and nutrient addition by freshwater runoff. Vertical density stratification is particularly strong offshore in central Hudson Bay, where it effectively prevents mixing of the surface and deep waters and thereby replenishment of nutrients above the pycnocline.

Freshwater runoff affects the primary productivity negatively by increasing vertical stability of the water column, and positively through nutrient additions--either direct or due to deep-water entrainment. While river runoff carries large quantities of carbon and nutrients into the marine ecosystem, particularly during ice-breakup, the river waters are less concentrated in nutrients than Hudson Bay coastal waters.

Biological productivity appears to be low relative to other oceans at the same latitude and comparable to that of seasonally open-water areas of Canada's Arctic Archipelago. It appears to be greatest in coastal waters, particularly at embayments and estuaries, and near islands where there is periodic entrainment or upwelling of deeper, nutrient-rich water. Productivity above the pycnocline and under the ice may be limited by the availability of nutrients, particularly nitrogen. In summer there is a layer of maximum primary productivity below the pycnocline in Hudson Bay. The historical presence of large numbers of bowhead whales suggests that there is an area of higher productivity in northwestern Hudson Bay. The structure of the food web in the Hudson Bay marine ecosystem is not well known, nor is the flow of energy through that web.

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6.0 PLANTS

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Phytoplankton, sea-ice microalgae, benthic algae, and macrophytes provide sustenance either directly or indirectly for animals in the Hudson Bay marine ecosystem. Two floral habitats, the eelgrass beds along the east coast of James Bay and salt marshes along the James Bay coast and southwestern coast of Hudson Bay, are particularly important to migratory waterfowl.

6.1 Phytoplankton

To our knowledge, phytoplankters have only been collected in the Hudson Bay marine region during the open water season, mostly from surface waters. Davidson (1931) collected surface samples from 13 stations in Hudson Bay during the Loubyrne Expedition; Bursa (1961) from northern Hudson Bay and along the west coast at the surface and depths of 10, 25, and 50 m during the Calanus Expeditions; and Brooks (1979) and Roff and Legendre (1986) from Chesterfield Inlet and northwestern Hudson Bay. Researchers aboard the C.G.S. Narwhal conducted a wide-ranging synoptic survey of phytoplankton in surface waters of the marine region during the summer of 1975--Gerrath et al. (1980) studied the phytoplankton of fresh water origins and Anderson et al. (1981) the marine diatoms and dinoflagellates. The Nelson River estuary was sampled during August and September of

1988 (Baker 1989) and 1992 (Baker et al. 1993), and the Churchill River estuary in September of 1993 (Baker et al. 1994) and July 1994 (Lawrence and Baker 1995). In August and September 1993, researchers aboard the MV Fogo Isle collected phytoplankton from the upper 50 m of the water column, and at discrete depths to 100 m at selected stations, along a north-south transect from the mouth of James Bay to Hudson Strait and an east-west transect across the mouth of Hudson Bay (Simard et al. 1996; Harvey et al. 1997).

Most studies of phytoplankters in the James Bay marine region have been conducted between mid-February and early October in the general areas of southeastern Hudson Bay (Anderson 1979; Legendre and Simard 1979; Anderson and Roff 1980a,b; Gerrath et al. 1980; Simard et al. 1980, 1996; Grainger 1982; Harvey et al. 1997); Manitounuk Sound and offshore Kuujjuarapik (Legendre and Simard 1979; Legendre et al. 1981, 1982, 1986); the Eastmain and La Grande estuaries in eastern James Bay (Foy and Hsiao 1976; Ingram et al. 1985); and Rupert Bay (Legendre and Simard 1978; De Sève 1993). Little is known of phytoplankton in central or western James Bay or in Richmond Gulf. Seasonal and depth-related changes in offshore phytoplankton species composition have not been documented.

Despite its northerly latitude, Arctic character, and low productivity, the Hudson-James Bay system has a remarkably diverse microalgal community, consisting of over 495 taxa (Roff and Legendre 1986; Harvey et al. 1997). The high diversity of the Arctic water phytoplankton is well known but not understood. It is a reversal of the general trend. Papers by Bursa (1961), Foy and Hsiao (1976), Legendre and Simard (1978, 1979), Anderson (1979), Gerrath et al. (1980), De Sève (1993), Simard et al. (1996), and Harvey et al. (1997) include extensive lists of phytoplanktonic species identified from the marine ecosystem.

The marine diatom and dinoflagellate assemblages in the southeastern Hudson Bay and James Bay do not differ significantly in species composition from those reported in Arctic and North Atlantic waters and are a mixture of arctic, boreal, and temperate forms (Davidson 1931; Bursa 1961, 1968; Anderson et al. 1981; Roff and Legendre 1986; Harvey et al. 1997). This mixture of flora is probably due in part to the presence of warm water relict species, as in the case of the fauna. Species distributions and assemblages appear to be related to the mixing of fresh and saline waters, with changes in temperature, nutrients, and light level all playing a part (Legendre and Simard 1979; Gerrath et al. 1980; Anderson et al. 1981; De Sève 1993). The surface waters are dominated by marine species that have restricted distributions in coastal areas where the effect of fresh water is strongest. Dilute nearshore estuarine waters are dominated by freshwater taxa that originate in the river and either accumulate or continue to grow in the estuary (Schnneider-Vieira et al. 1993). Some typical summer surface species assemblages that occur in Hudson Bay are listed in Table 6-1.

In their survey of Hudson Bay during the summer of 1975, Anderson et al. (1981) found that marine diatoms were most abundant (= 105 cells·L^{-1}) in samples taken northwest of the Belcher Islands. The moderating influence of relatively warm waters flowing from James Bay early in the spring and late in the fall may cause production in this area to begin earlier and continue later than elsewhere in Hudson Bay. Diatom cell numbers generally were lower and more variable adjacent to major river outflows, while dinoflagellates (Anderson et al. 1981) and freshwater forms (Gerrath et al. 1980) tended to have higher concentrations in these areas, with a definite exclusion of marine forms that were otherwise found throughout Hudson Bay. Dinoflagellates were most abundant in samples taken from the plume of Chesterfield Inlet and from immediately south of Mansel Island (Anderson 1979; Anderson et al. 1981). Samples with the greatest diversity of marine diatoms and dinoflagellates were taken between Coats and Mansel islands, and probably reflect the mixing of species from Hudson Bay with those from Hudson Strait (Bursa 1961; Anderson et al. 1981). Species diversity varied in the offshore waters following no discernable pattern, while inshore it was generally higher except along the lower west and southwest coast (Anderson et al. 1981). The area along the southwest coast appears to be less hospitable to marine diatoms and dinoflagellates than the rest of Hudson Bay, and has large populations of a small number of freshwater algal species (Gerrath et al. 1980).

Table 6-1. Distributional groupings of diatoms and dinoflagellates in the surface waters of Hudson Bay, including the area south and west of the Belcher Islands, during August and September 1975 (after Anderson et al. 1981).

Species grouped by distribution		Distribution
Div. Bacillariophyta (diatoms)		
Group A	*Chaetoceros compressus* Lauder	More common, widespread species. Present in from 53 to 90 of the 130 samples. Found throughout Hudson Bay except in the southwest coast area--particularly in waters adjacent to the Churchill and Nelson rivers.
	Chaetoceros septrionalis Ostrup	
	Leptocylindrus danicus Cleve	
	Leptocylindrus minimus Gran	
	Pseudonitzschia delicatissima (Cleve) Heiden	
	Nitzschia longissima (Brebisson *in* Kutzing) Grunow	
	Nitzschia seriata Cleve	
	Thalassionema nitzschioides (Grunow) Van Heurck	
Group B	*Chaetoceros atlanticus* Cleve	Common, widespread species. Present in from 12 to 32 of the 130 samples. Distribution similar to Group A.
	Chaetoceros neogracile VanLandingham	
	Rhizosolenia alata Brightwell	
	Rhizosolenia hebetata var. *semispina* (Hensen) Gran	
	Thalassiosira gravida (Cleve)	
	Thalassiosira nordenskioeldii Cleve	
	Thalassiothrix frauenfeldii (Grunow) Cleve et Grunow	
	Coscinodiscus sp. Ehrenberg	
Group C	*Chaetoceros decipiens* Cleve	Common, inshore species. Present in from 11 to 30 of the 130 samples. Common in most inshore areas including the southwest coast. Not usually found in the offshore; noticeably rare north of the Ottawa Islands and in the Coats and Mansel islands area. Other commmonly occurring species were found locally, inshore.
	Chaetoceros diadema (Ehrenberg) Gran	
	Chaetoceros convolutus Castracane	
	Chaetoceros laciniosus Schutt	
	Rhizosolenia setigera Brightwell	
Group D	*Asteromphalus ? heptactis* (Brebisson) Ralfs in Pritchard	Uncommon species. Present in from 1 to 5 of the 130 samples. Most occurred in the Coats and Mansel islands and (or) along the east coast of Hudson Bay.
	Chaetoceros lorenzianus Grunow	
	Chaetoceros fragilis Meunier	
	Chaetoceros wighami Brightwell	
	Coscinodiscus curvatulus Grunow in Schindt et al.	
	Coscinosira polychorda (Gran) Gran	
	Eucampia groenlandicus Cleve	
	Rhizosolenia ? delicatula Cleve	
	Rhizosolenia fragilissima Bergon	
	Rhizosolenia pungens Cleve - Euler	
	Rhizosolenia styliformis Brightwell	
	Thalassiosira decipiens Grunow	
	Thalassiosira ? hyalina (Grunow) Gran	
Group E	*Astrionella formosa* Hassall	Freshwater species. Usually present in from 1 to 3 of the 130 samples. Most occurred close to shore adjacent to areas of major freshwater discharge. *F. crotonensis* and *A. gracillima* were more common and widely distributed in coastal waters, and the former was also found offshore.
	Astrionella gracillima (Hantzsch) Heiberg	
	Caloneis bacillum (Grunow) Cleve	
	Cocconeis sp. Ehrenberg	
	Cyclotella comta (Ehrenberg) Kuntzing	
	Fragilaria ? capucina Desmazieres	
	Fragilaria crotonensis Kitton	
	Melosira ? granulata (Ehrenberg) Ralfs in Pritchard	
	Melosira islandica O. Muller	
	Melosira ? italica (Ehrenberg) Kutzing	
	Stephanodiscus ? hatzschii Grunow	
	Tabellaria flocculosa (Roth) Kutzing	

Table 6-1. continued.

Species grouped by distribution		Distribution
Div. Pyrrhophyta (dinoflagellates)		
Group F	*Amphidinium longum* Lohmann *Gymnodinium arcticum* Wulff *Gyrodinium pingue* (Schutt) Kofoid and Swezy *Gyrodinium spirale* (Bergh) Kofoid and Swezy	More common, widespread species. Present in from 59 to 93 of the 130 samples. Found throughout Hudson Bay except for a small area off the Nelson and Severn rivers.
Group G	*Amphidinium ? crassum* Lohmann *Amphidinium phaeocysticola* Lebour *Ceratium arcticum* (Ehrenberg) Cleve *Ceratium longipes* (Bailey) Gran *Dinophysis acuminata* Claparede and Lachman *Dinophysis arctica* Mereschkowsky *Dinophysis rotundata* Claparede and Lachman *Peridinium globulus* Stein var. *quarnerense* Schroeder *Peridinium depressum* Bailey	Common to rare species found concentrated in the Coats and Mansel islands area and along the east coast of Hudson Bay--a distribution similar to the diatoms of Group D, and also close to shore along the west coast south to Churchill. Present in from 1 to 6 of the 130 samples with the exception of *P. globulus* var *quarnerense*, which was found in 19 samples.
Group H	*Massartia rotundata* (Lohmann) Schiller *Peridinium pallidum* Ostenfeld *Peridinium pellucidum* (Bergh) Schutt	Common species. Found in 15 to 23 of the 130 samples. Occur mainly along the southwest coast, in the Chesterfield Inlet area and a small area south of Mansel Island. The remaining dinoflagellate species constituted no apparent grouping.

Three distinct species assemblages were identified along a sampling transect from the mouth of James Bay to Hudson Strait in early September 1993 (Harvey et al. 1997; Figure 6-1). The southernmost group (A), was strongly influenced by freshwater runoff entering James Bay and southern Hudson Bay. The most strongly stratified and enriched with particulate organic nitrogen from freshwater runoff, this area was characterized by a relatively high phytoplankton biomass (chlorophyll ***a*** (Chl ***a***) >1.0 $\mu g \cdot L^{-1}$) in the near surface waters (Figure 6-2) and by a brackish-marine phytoplankton community equally dominated by small flagellates and dinoflagellates; (Figure 6-1). The second group (B) occurred northwest of the Belcher and Sleeper islands. It was less influenced by freshwater runoff and was characterized by relatively well-mixed conditions; small diatoms composed about 50% of this phytoplankton assemblage. The third group (C) occupied northern Hudson Bay and western Hudson Strait, an area characterized by the lowest surface nutrient concentrations and a subsurface chlorophyll maximum. Small flagellates were numerically dominant in this area, comprising over 55% of the species assemblage.

Species typical of fresh water are common in the offshore waters of Hudson Bay, where they occur in apparently good condition up to 400 km offshore and 2 months after the disappearance of ice cover (Bursa 1961; Gerrath et al. 1980; Roff and Legendre 1986). Bursa (1961) referred to this phenomenon as "Arctic neritism". During the summer of 1975 the highest surface cell counts (= 10^6 cells$\cdot L^{-1}$) of freshwater taxa occurred in the area of depressed salinity along the southern coast of Hudson Bay (Gerrath et al. 1980). Most were blue green algae (Cl. Cyanophyceae), green algae (Cl. Chlorophyceae), diatoms (Cl. Bacillariophyceae), or golden-brown algae (Cl. Chrysophyceae), and the species diversity tended to be highest inshore. Eight freshwater species were identified at one station northwest of the Belcher Islands, where they comprised 19% of the total cell count—their relative contribution to the biomass was not determined. The origins of these freshwater algae are not known, but they may develop in melt pools on the ice or be distributed under the ice by spring runoff.

In James Bay, Grainger (1976) identified three distributional groups of phytoplankton: arctic, euryhaline, and freshwater. The euryhaline group dominates nearly everywhere, especially in and near the La Grande River estuary, and tolerates a wide range of physical properties of the water. Diatoms dominate, but blue-green and green algae are also plentiful near the mouth of the La Grande River. The same is true of the Churchill River estuary in southern Hudson Bay (Baker et al. 1994; Lawrence and Baker 1995). Ingram et al. (1985) noted the appearance of typically marine phytoplankters in the estuary of the Eastmain River following its diversion, indicating a shift to a more marine environment. In the estuarine environment of Rupert Bay, summer

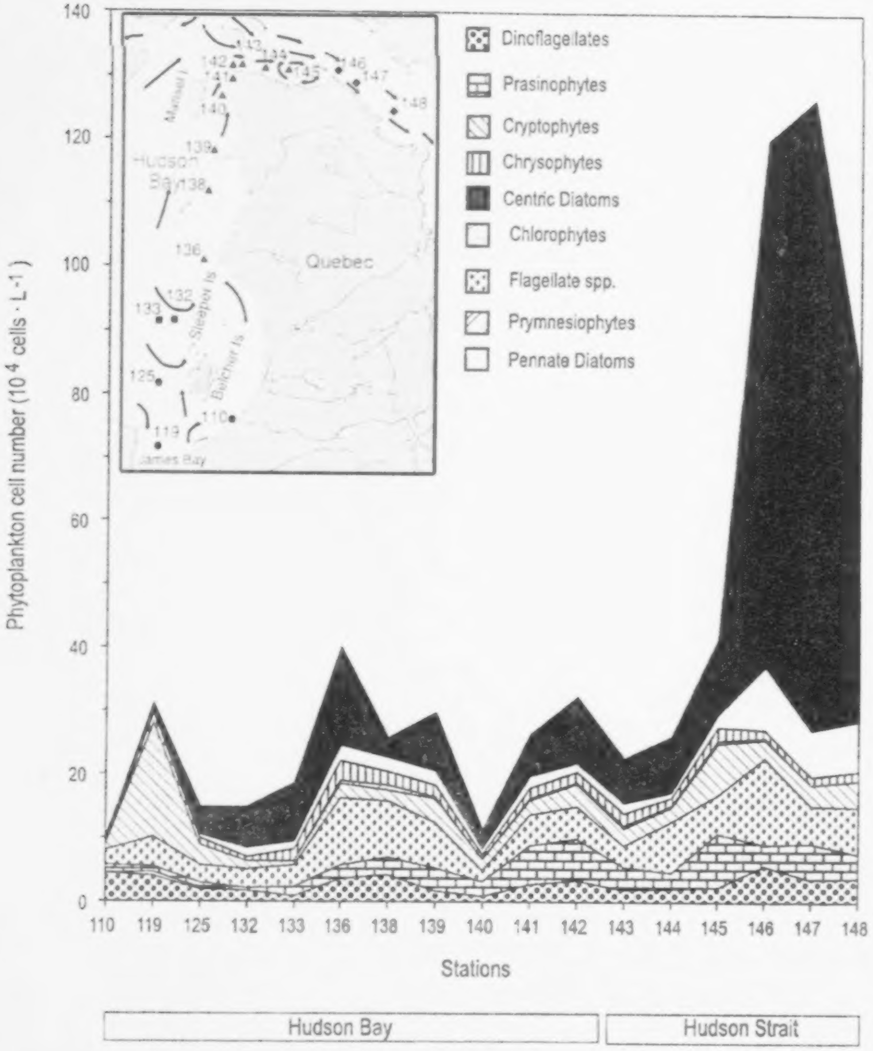

Figure 6-1. **Phytoplankton distribution along a sampling transect (inset) in Hudson Bay and Hudson Strait (adapted from Harvey et al. 1997). The map symbols indicate distinct phytoplankton assemblages that were identified by cluster analysis (● group A; ■ group B, ▲ group C, ◆ group D).**

phytoplankton dynamics are controlled by the tidal and seasonal hydrography, as well as by the high sediment load and the limiting phosphate level of these waters (Legendre and Simard 1978; De Sève 1993).

The summer phytoplankton cycle in the Belcher Islands area showed the normal cold-water sequence of dinoflagellates succeeding diatoms (Grainger 1982). Diatoms dominated numerically, reaching maximum numbers of 4.5 x 10^5 cells·L^{-1} in June with a second maximum in early August, followed by a drastic decline in numbers later in the month (Figure 5-28). The diatom decline may be attributable to predation by ciliates, which became exceptionally abundant at the Belcher Islands in August. Ciliates may play a significant role in the food chain, serving as important consumers of the nanoplankton and microphytoplankton, and as prey for the larger omnivorous zooplankton.

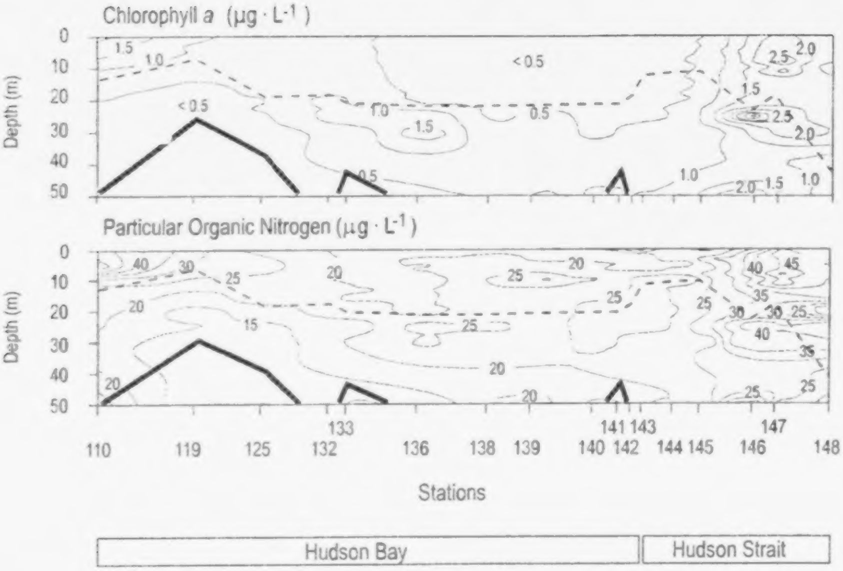

Figure 6-2. **Horizontal and vertical distribution of chlorophyll *a* and particulate organic nitrogen in the upper 50 m of the water column along a sampling transect in Hudson Bay and Hudson Strait in September 1993 (adapted from Harvey et al. 1997). Also shown are: the depth of the mixed layer (----), which was defined as the depth where the temperature was 1°C less than at the surface; the lower depth limit of the pycnocline (—); and an index of vertical stratification (•—•), which was defined as the difference in density between the bottom and surface layers ($\Delta\sigma t$). See Figure 6-1 for station map and Figure 5-22 for STD and dissolved nutrient distributions.**

Phytoplankton blooms typically occur when the upper water column is relatively stable and nutrient rich (Legendre et al. 1982). In exposed areas, these conditions may only occur under the ice in late April and May, as the light increases and the upper water column is stabilized by low-salinity melt water (Legendre et al. 1981). The resultant under-ice bloom is augmented by the release of ice algae. In sheltered embayments such as Manitounuk Sound, where local winds and fortnightly tides combine to cause cycles of relative instability and stability of the water column, phytoplankton blooms can also occur intermittently during the summer (Legendre et al. 1982). These blooms occur once the upper water column has stabilized following a period of nutrient regeneration through mixing. A strong phytoplankton bloom also occurred in the Eastmain River estuary when the water column stabilized following the diversion of flow into the La Grande River and the incursion of marine water into the estuary (Ingram et al. 1985).

In southeastern Hudson Bay, the mid-summer chlorophyll **a** maximum generally occurs in the upper 20-25 m (Grainger 1982) at or above the pycnocline (Anderson and Roff 1980b). The strong subpycnocline chlorophyll **a** maxima observed by Anderson and Roff (1980a,b) in the offshore waters of Hudson Bay (Figure 5-27) have not been observed inshore or in the James Bay marine region, where their formation may be precluded by higher surface chlorophyll levels and concentrations of total seston, and lower light penetration.

Seasonal and depth-related changes in phytoplankton species composition have not been documented. They may be significant since phytoplankters float more or less passively, following the currents, and species composition changes with the changing properties of the mixing waters (Bursa 1968).

Primary production reaches rates of over 3 mg $C{\cdot}m^{-3}{\cdot}h^{-1}$ (Grainger 1982) near the Belchers and about 2.5 mg $C{\cdot}m^{-3}{\cdot}h^{-1}$ in Manitounuk Sound (Legendre and Simard 1979). This translates to an annual primary productivity rate of about 35 g C·m^{-2}·a^{-1}, not including ice algal production or the main spring diatom bloom (Roff and Legendre 1986). This annual primary productivity is similar to that for phytoplankton in other seasonally ice-free Arctic marine waters (Subba Rao and Platt 1984). Dilute estuarine waters tend to be nutrient poor and appear to have lower primary production than areas outside their influence (Schneider-Vieira et al. 1993). Organic debris appears to be an important base for the estuarine food chain.

No evidence was found for the existence of red tides in Hudson Bay or James Bay. This phenomenon, which is a threat to public health in some marine areas, is caused by dinoflagellates of the genus *Gonyaulax*—in particular *G. excavata* on the east coast and *G. catenella* and *G. acatenella*, which produce the toxins causing paralytic shellfish poisoning (PSP) (White 1980). Bivalve molluscs that consume these dinoflagellates accumulate the neurotoxins in their soft tissues, which may then be eaten by people. Dinoflagellates of the genus *Gonyaulax* have not been recorded from the region (Bursa 1961; Anderson 1979; Roff and Legendre 1986), nor has PSP been found in the testing of mussels (Jamieson 1986; Giroux 1989; M. Hentzel, DFO Winnipeg, pers. comm. 1993).

6.2 Ice microalgae

In springtime, the bottom 1 to 5 cm of Arctic and Antarctic sea ice is generally colonized by dense populations of microalgae, and there are often high concentrations of free-floating microalgae at the ice-water interface (e.g., Demers et al. 1986; Horner et al. 1992; Legendre et al. 1992a). The structure and dynamics of these ice algal communities has been studied intensively in southeastern Hudson Bay and Manitounuk Sound (e.g., Poulin and Cardinal 1982a, 1982b, 1983; Poulin et al. 1983; Gosselin et al. 1985, 1986, 1990; Rochet et al. 1985, 1986; Maestrini et al. 1986; Legendre et al. 1987, 1996; Barlow et al. 1988; Michel et al. 1988, 1989; Demers et al. 1989; Tremblay et al. 1989; Robineau et al. 1994; Monti et al. 1996). Most of the research has been conducted between late-March and mid-May. Little is known of the communities at other times or elsewhere in Hudson Bay or James Bay, except near Saqvaqjuac in northwestern Hudson Bay (63°39'N, 90°39'W; Bergman et al. 1991; Welch et al. 1991).

The ice algal community of southeastern Hudson Bay is diverse. At least 151 taxa have been identified, including 142 diatoms (Bacillariophyceae), 3 dinoflagellates (Dinophyceae), 2 green algae (Chlorophyceae), 1 golden brown alga (Chrysophyceae), 1 blue-green alga (Cyanophyceae), 1 Eugleniod and a number of microflagellates (Poulin and Cardinal 1982a+b, 1983; Poulin et al. 1983). *Nitzschia* and *Navicula* species usually dominate the community during the April and May ice-algal blooms (Figure 6-3 and Figure 6-4) (Rochet et al. 1985; Barlow et al. 1988; Michel et al. 1988). The species composition changes seasonally with *Nitzschia frigida*, the dominant species, decreasing noticeably in mid-May, possibly due to the detrimental effects of lower salinity and/or photoinhibition (Barlow et al. 1988). *Navicula* spp. may be more tolerant of these conditions.

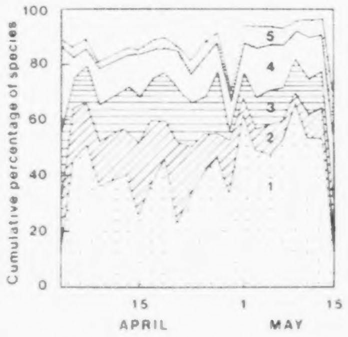

Figure 6-3. Species composition of the sea-ice microalgal community at the ice-water interface 22 km offshore Kuujjuarapik (55°30.1'N, 77°44.9'W): 1) *Nitzschia frigida*, 2) *Nitzschia* spp., 3) *Navicula pelagica*, 4) flagellates, and *Chaetoceros* spp. (from Michel et al. 1988, p. 180).

Temperature, light, salinity, and nutrients have been identified as the main environmental factors regulating the growth of sea-ice microalgae (Demers et al. 1986; Roff and Legendre 1986; Bergmann et al. 1991; Welch et al. 1991; Legendre et al. 1992b, 1996; Monti et al. 1996). Physiological adaptations to temperature and light enable the algae to cope with short-term and seasonal changes in their environment, and may explain seasonal changes in production, patchy horizontal distributions, species successions, and so on (Legendre et al. 1989).

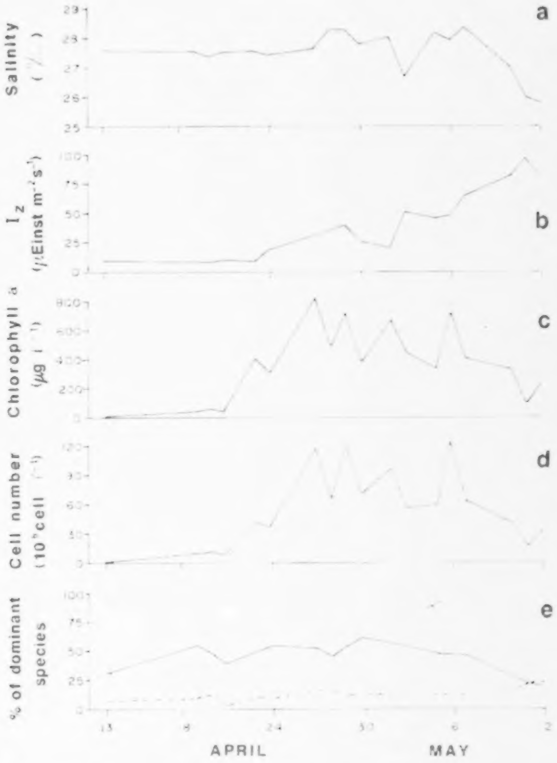

Figure 6-4. **Seasonal variation of: a) salinity, b) under-ice photon fluence rate Iz, c) chlorophyll a concentration, d) cell number, and e) the dominant species *Nitzschia frigida* (—), *Navicula* spp. (·····), and *Nitzschia* spp. (-----) at the ice-water interface, 27 km offshore Kuujjuarapik (55°30.1'N, 77°44.5'W) (from Barlow et al. 1988, p. 146).**

Ice algae grow under conditions of low and relatively constant temperature (-1.7 to 0°C; e.g., Gosselin et al. 1985; Rochet et al. 1985). They are not obligate shade flora but rather adapt to optimize the use of ambient light energy (Barlow et al. 1988). Photosynthetic activity does not begin until light intensity reaches 7.6 $\mu E \cdot m^{-2} s^{-1}$ (Gosselin et al. 1985). Under the low light conditions of early spring (<9 $\mu E \cdot m^{-2} s^{-1}$) the algae maintain photosynthesis by increasing their light trapping efficiency (shade adaptation) (Barlow et al. 1988). Later in the season, as the light gets stronger, they respond by increasing their rate of photosynthesis (light adaptation). This transition from shade to light adaptation takes place over one generation time (8-17 d; Maestrini et al. 1986) (Michel et al. 1988). It enables the algae to start developing at very low irradiance and may improve their photosynthetic output.

Ice algae respond to changes in the spectral quality of their light environment by rapidly (8 h) rearranging the relative proportions of their photosynthetic pigments (Rochet et al. 1986; Michel et al. 1986). This may be an important ecological adaptation to the under-ice environment, where light is often subjected to rapid variations in spectral quality as a result of shifting snow cover. The ability to adapt chromatically may become a critical factor for species competition, in a context of limiting light and nutrient resources.

The dynamics of ice-algal communities are controlled not only from above by seasonal changes in light intensity, but also from below by shorter-term hydrodynamic events (Maestrini et al. 1986; Demers et al. 1989; Ingram et al. 1989; Gosselin et al. 1990). Following an initial period of light limitation, the ice-algal growth becomes nutrient-limited when in situ irradiance and the accumulated algal biomass are high and the tidally driven nutrient supply is not strong enough to satisfy algal requirements. Vertical mixing, primarily by the fortnightly tides, replenishes nutrients at the ice-water interface, periodically enhancing growth of the ice algae. In spring, higher freshwater inputs result in deepening of the pycnocline, which acts to limit mixing and thereby nutrient input to the ice-water interface (Ingram et al. 1989). The availability of nitrates may limit the growth of inshore ice algae at Saqvaqjuac, where the maximum ice algal biomass was an order of magnitude higher over deep water, about 170 mg Chl **a**·m^{-2}, than over shallow water (Bergmann et al. 1991; Welch et al. 1991). Nitrogen uptake by kelp may be a factor contributing to the lower nitrate concentration in these shallow waters (Welch et al. 1991).

The distribution of microalgae under the sea ice is patchy (Gosselin et al. 1986; Bergmann et al. 1991). On a large scale (30 km) it is directly related to salinity, which affects the ice surface available for colonization; on a smaller scale (0.3-500 m) by variations in the thickness of snow-ice cover, which affects illumination (Figure 6-5). Early in the season the low irradiance limits photosynthesis so that algal patches tend to develop in lighted areas under thin snow-ice cover, whereas later in the season the maximum growth occurs in areas that offer protection from photoinhibition (Gosselin et al. 1986). In Manitounuk Sound and southeastern Hudson Bay these patches are about 20 to 90 m in diameter. High concentrations of ice flora are often associated with brine

Figure 6-5. Typical light values in April and May, showing attenuation through snow, ice, and the algal layer (from Bergmann et al. 1991, p. 46). Surface reflectance (albedo) is about 60%.

channels within the ice, where nutrient concentrations are thought to be much higher than in surrounding water (Demers et al. 1989).

At Manitounuk Sound, Gosselin et al. (1985) observed the maximum concentrations of ice-algal cells and chlorophyll ***a*** on 7 May at the ice-water interface and also in the bottom 20 cm of ice (12 x 10^8 cells·m^{-2} and 0.85 mg Chl ***a***·m^{-2}). Poulin et al. (1983) reported similar values. These chlorophyll ***a*** concentrations vary greatly in Arctic waters. The observed values are low relative to many areas, including Resolute and Saqvaqjuac (Welch et al. 1991), but within the ranges reported by Dunbar and Acreman (1980) from Robeson Channel and Hudson Bay. Offshore Grande rivière de la Baleine, the taxonomic diversity and biomass of ice algae at the ice-water interface are greater at the edge of the freshwater plume than within or beyond it (Monti et al. 1996). This may reflect a greater diversity of habitats for the ice algal taxa at the plume edge.

During the spring blooms, a portion of the ice algal production (20%) is exported to the benthos, either as sinking cells or fecal pellets of herbivores, while the remainder may be retained in the pelagic environment (Tremblay et al. 1989). During and immediately after the bloom, ice algae are an important source of food for the marine planktonic copepods *Calanus glacialis* Jaschnov and *Pseudocalanus minutus* (Krøyer) (Runge and Ingram 1991; Tourangeau and Runge 1991).

The quantitative contribution of ultra-algae (<5 μm) to total primary production is remarkable when compared to that of larger cells such as diatoms (Robineau et al. 1994, 1999). These tiny algae occur primarily in the sea-ice bottom but also at the ice-water interface. In April and May 1990, offshore Kuujjuarapik (55°30.1'N, 77°44.5'W), they occurred at concentrations ranging from 36 x 10^3 to 63 x 10^6 cells·L^{-1} and contributed from 9 to 96% of the total chlorophyll ***a***. Availability of a solid substratum was the main factor controlling their abundances, which varied primarily with depth but also with distance from shore and with time. The ice bottom, ice-water interface, and water column formed distinct habitats that were colonized by different taxonomic assemblages. Eucaryotes dominated the high concentrations of ultra-algae in the ice and at the ice-water interface, and this dominance increased with distance from shore; procaryotes (Cyanobacteria) dominated the low concentrations of ultra-algae found in the water column, and were mainly associated with the dilute waters of the river plume and overlying ice cover.

6.3 Benthic algae

Knowledge of benthic algae in the Hudson Bay marine ecosystem is limited largely to the identification of macrobenthic species. At least 94 macro benthic algae have been identified from James Bay and southeastern Hudson Bay including 42 Phaeophyceae, 33 Rhodophyceae, 18 Chlorophyceae, and 1 Xanthophyceaen (Setchell and Collins 1908; Howe 1927; Bell and MacFarlane 1933; Breton-Provencher and Cardinal 1978; Lee 1980--see also Gardner 1937, 1949; Bell and MacFarlane 1938; Whelden 1947; Cardinal 1990). Appendix 1 lists the taxa, together with comments on collection locations, and occurrence. Little is known of either species distributions or species-habitat associations.

The total number of taxa reported is low relative to other seas at similar latitudes, and none of the species is endemic to this region (Breton-Provencher and Cardinal 1978). Ice scour prevents the establishment of a rich bottom flora in shallows and nearshore, and soft mud bottoms may be limiting to species that need a solid substrate for attachment (Bursa 1968). Sunlight, nutrient availability, and water temperature may also affect the establishment of bottom flora. Studies at Rupert Bay, the mouth of the Eastmain River, and Manitounuk Sound found the mean number of taxa per station and the biomass to be relatively low (Breton-Provencher and Cardinal 1978). This may be related to the salinity, which is sometimes much reduced, to soft sediments and high sedimentation rates, and ice cover and scour. Only 7 species of macroalgae were identified from Rupert Bay, each tolerant of a wide range of salinity.

In Hudson Bay, green algae are generally most abundant in the upper littoral zone, brown algae at intermediate depths, and red algae in deep water (Bell and MacFarlane 1933). Two brown algaes, *Pylaiella littoralis* (L.) Kjellm. and *Fucus evanescens* Ag., occur in the intertidal zone, the latter in dwarfed form. *Laminaria*, *Agarum*, *Fucus*, and *Alaria* can be found washed up on beaches (Bursa 1968), where they are sometimes eaten by polar bears in the summer (Russell 1975).

Macroalgae grow on the seafloor of Hudson Bay to a depth of at least 75 m (Barber 1983). A number of underwater photographs were taken by the M.V. Theta at a depth of 55 m in Omarolluk Sound, Belcher Islands (56°10'N, 78°58'W; Barber et al. 1981; Barber 1983). It would be interesting to examine them for the presence of benthic macroalgae. Northern coastal areas and estuaries in the vicinity of Chesterfield Inlet are also characterized by clear waters and a very deep photic zone that permits extensive growth of attached algae (M. Bergman pers. comm. cited in Schneider-Vieira et al. 1993).

6.4 Benthic vascular plants

James Bay is unusual among Canada's Arctic marine regions in having extensive beds of vascular aquatic plants. Subtidal meadows of eelgrass (*Zostera marina* L.), known in Cree as *shiikaapaashkw*, flourish along the eastern coastline of James Bay north of Vieux-Comptoir (Curtis 1973c, 1974/5; SEBJ 1990; Dignard et al. 1991; Lalumière et al. 1994; Ettinger et al. 1995; Julien et al. 1996), and along the coasts of Akimiski Island (Porsild 1932; Smith 1944 cited in Curtis 1973c) (Figure 6-6). Eelgrass also occurs sporadically along the southwestern coast of Hudson Bay north to at least Arviat (Porsild 1932; Bursa 1968). These seed plants colonize areas that are sheltered from wave action and drift ice, have a low tidal range, gentle current =50 $\text{cm}\cdot\text{s}^{-1}$, and fine, gently-sloping bottom sediment that is between 0.5 and 4 m below the average low tide (SEBJ 1990; Dignard et al. 1991; Lalumière et al. 1994). In these areas, the water temperature ranges from -1 to +20°C, and during the growth season the salinity ranges from 10 to 25 ppt (≈psu) and the illumination is at least 1% of that received at the surface. Summer salinities of <10 ppt and possibly substrate instability may explain the absence of eelgrass from the large estuaries.

The eelgrass beds generally are monospecific in deeper waters but in shallow water are often associated with other vascular plants, *Potamogeton pectinatus* and, more rarely, *Ruppia maritima*, and a variety of benthic algae (Dignard et al. 1991; Lalumière et al. 1994). Towards the open sea the eelgrass meadows generally give way to the brown benthic macroalgae *Fucus distichus* and *Ascophyllum nodosum*.

Depending on conditions, *Zostera marina* grows at a density ranging from 50 to 1761 $\text{shoots}\cdot\text{m}^{-2}$ and produces a dry biomass of 30 to 675 $\text{g}\cdot\text{m}^{-2}$ (SEBJ 1990; Lalumière et al. 1994). Reproductive shoots average 5% of the population but can in some places reach 20%. Blades of the most vigorous plants reach 5 mm in width and 2.5 m in length (Dignard et al. 1991; Lalumière et al. 1994). The density and biomass of the beds vary with location and year in response to the effects of waves and currents, ice, turbidity, water temperature, and illumination (SEBJ 1990; Lalumière et al. 1994). While less dense and productive than beds in Alaska, which have densities of 788 to 5033 $\text{plants}\cdot\text{m}^{-2}$ and biomasses of 136 to 1840 g dry $\text{weight}\cdot\text{m}^{-2}$ (McRoy 1970), the eelgrass beds in James Bay still form the base of major food chains (Curtis 1974/5).

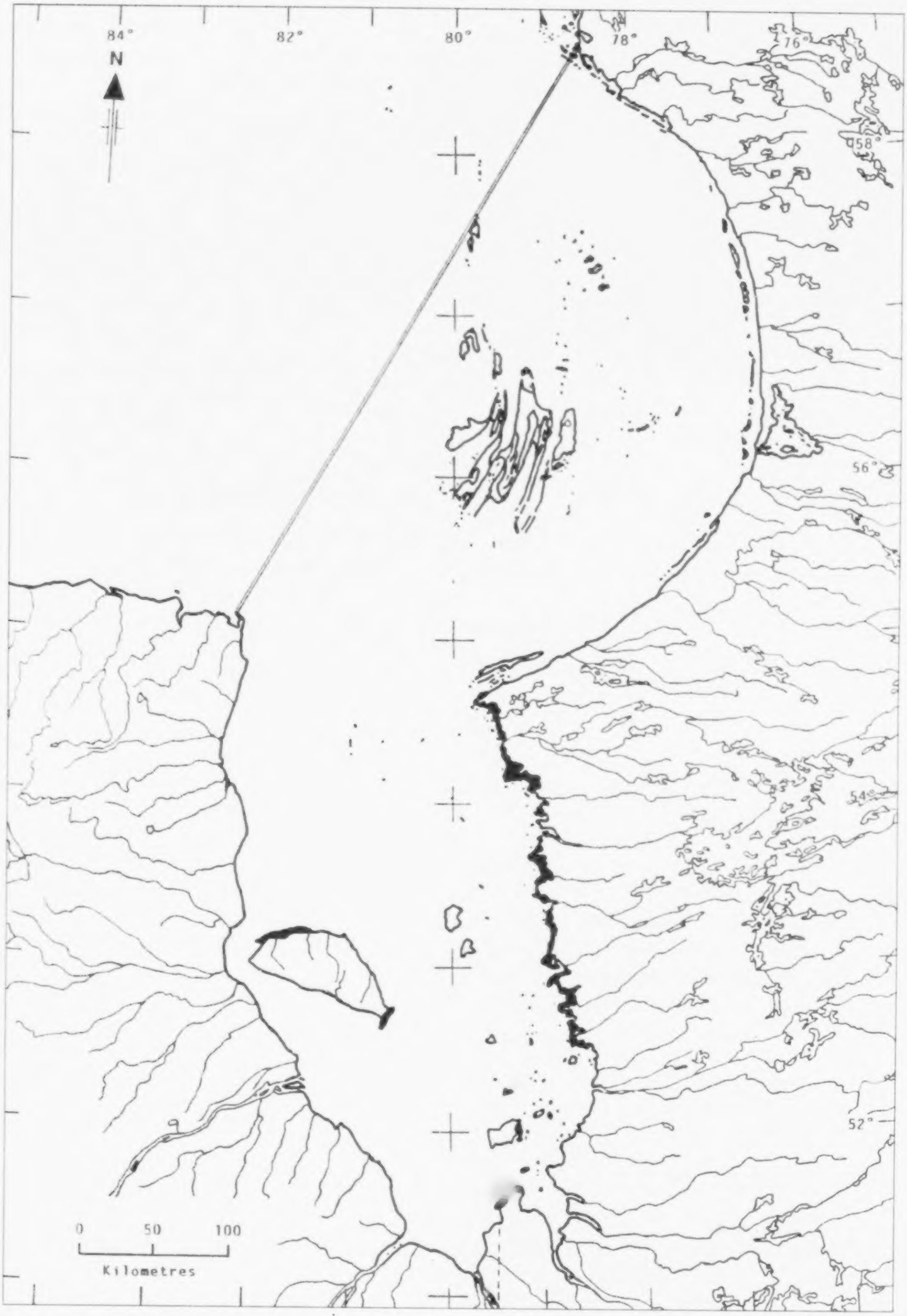

Figure 6-6. Distribution of eelgrass beds in the James Bay marine region (after Curtis 1973c, 1974/5; Dignard et al. 1991).

Eelgrass beds of varying density and size are found along the entire James Bay coastline of the Wemindji Cree territory (Ettinger et al. 1995). These beds vary from dense, nearly continuous fields to thin patches. Cree hunters who use the area extensively have observed increases in the size, density, and number of beds over much of this coastline in recent years. This change has made coastal navigation more difficult but is viewed positively overall, as it provides important food for brant and other waterfowl during their fall migrations. Plants in deeper areas are a dark, rich green and can be up to 9 m long, while those in shallower areas, where they are exposed at low tide, or in low salinity are shorter and a pale or dull green. When the ice breaks up early in the spring the plants grow better and hunters expect to have difficulty travelling in some areas in the late summer and early fall. Travel must be timed to avoid getting stuck in a grass-filled bay at low tide.

The effects of ice on the eelgrass beds are complex and vary with location and year (Ettinger et al. 1995). Ice can be very damaging if the plant's roots are frozen or pulled out or scoured off the bottom. Water depth, ice thickness, local currents, the amount of runoff, spring tides or storm surges, and the timing and speed of breakup can all interact to affect the eelgrass beds. Whether ice promotes eelgrass growth by removing old growth or inhibits it by damaging the beds may depend largely on the depth to which it freezes.

The leaves, seeds, and rhizomes of eelgrass are very important foods for several species of waterfowl (Curtis 1974/5; Curtis and Allen 1976; Dignard et al. 1991; Lalumière et al. 1994; Ettinger et al. 1995). In spring, brant stop on their northward migration to graze on the eelgrass beds through cracks in the sea ice. Canada geese and American widgeons may also exploit this food source. In autumn, the eelgrass is eaten by large numbers of brants and Canada geese, American widgeons, American black ducks, and northern pintails. Diving ducks also frequent the eelgrass beds during their summer moult and in the autumn to feed on epiphytic organisms and other biota (Curtis 1974/5; Dignard et al. 1991). The large concentrations of brants observed in the Pisquamish and North Point areas of the Ontario coast apparently feed on eelgrass that has drifted there from the beds on Akimiski Island (Curtis 1973c). Damage to the eelgrass beds could have serious ecological consequences, particularly for waterfowl (Curtis 1974/5).

Large eelgrass beds have a calming effect on wave action, and stabilize sediments thereby providing shelter and feeding areas for a variety of marine biota (Curtis 1974/5). A variety of molluscs, annelids, cnidarians, and bryozoans grow on the plants; oligochaetes are common in the fine sediment; and the beds provide habitat for juvenile sculpins, Greenland cod, coregonids, and lake trout (SEBJ 1990; Lalumière et al. 1994). The calming effect also enables Cree fishermen to set nets during fairly rough weather in areas protected by eelgrass beds.

6.5 Salt marshes

Salt marshes, as discussed earlier in Section 3.3.1, are widely distributed along the coasts of Canada but are a particularly important and characteristic feature of western James Bay (Figure 6-7). They are also present along the southwestern coast of Hudson Bay, where they tend to be confined to large estuaries and areas protected by barrier islands (Kershaw 1976; D. Punter, Univ. of Manitoba, Winnipeg, pers. comm. 2005). Indeed, the presence of a physical feature that provides protection from wave action is a prerequisite for their occurrence (Long and Mason 1983). Five types of salt marsh have been distinguished on the basis of the form this protection takes: 1) lagoonal marshes (partially enclosed); 2) beach plain marshes (fairly open to wave action); 3) barrier island marshes (partially protected by a chain of offshore islands); 4) estuarine marshes (protected by the estuarine morphology itself); and 5) artificial marshes (made by human activity). At least three of these types (numbers 2, 3 and 4) are found in the Hudson Bay marine ecosystem (Stewart et al. 1993).

Salt marshes are very important to the marine ecosystem for their biological productivity and the habitat they provide other biota (Stewart et al. 1993). They support a large invertebrate population, which in turn supports a large vertebrate fauna including fish, small mammals, and birds. Beds of eelgrass (*Zostera*) are frequently associated with the salt marshes, and occupy the lowest level in the shore slope above the low-tide range (Figure 6-7; Clarke et al. 1982).

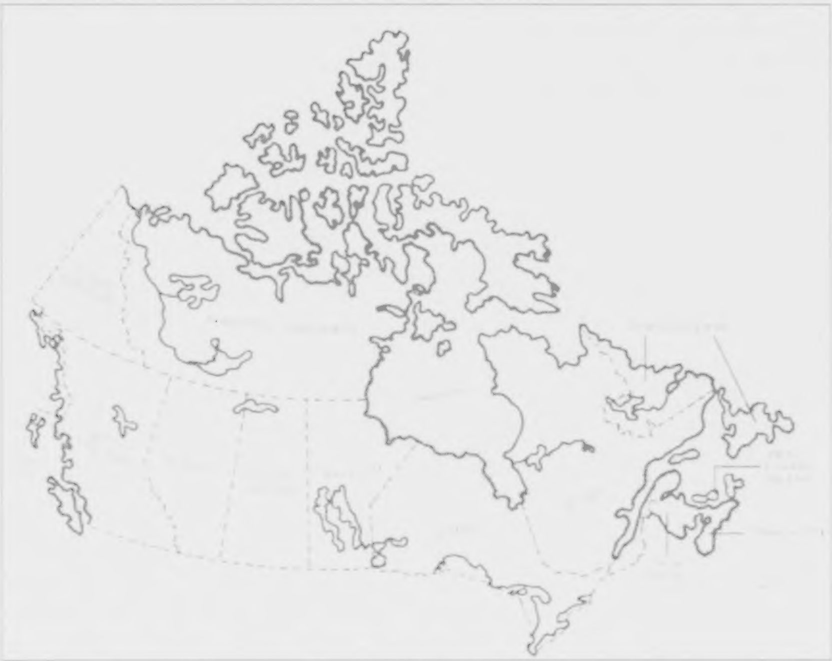

Figure 6-7. **Distribution of salt marshes in Canada (from Canada 1988, Canadian Wetlands Working Group). Stippling indicates the approximate range of occurrence of salt marsh, not its continuous presence**

The importance of salt marsh habitat to migratory birds that visit the shores of western James Bay is well described by Martini et al. (1980b), from which Figure 6-8 is taken. The same paper has an excellent treatment of marsh birds of the whole region, and is quoted at length here. Figure 6-9, also from that paper, shows the localities mentioned in text and the distribution of marshlands and concentrations of bird species. Martini et al. (1980b) write as follows:

> "**Shorebirds**. *The Hudson Bay Lowland supports an extensive avifauna, nearly all of which is migratory. The two most important groups utilizing the coastal flats and marshes are shorebirds and waterfowl.*
>
> "*In general, shorebirds found in James Bay breed in arctic or subarctic areas and undertake long migrations to wintering grounds ranging from the Atlantic and Gulf coasts of the United States of America to the southern parts of South America. Although some of the species breed along coastal and inland areas of James Bay, the coast is most important to shorebirds on migration, and contains areas of outstanding international importance for several species. The most prominent species are the Hudsonian Godwit (*Limosa haemastica*), Red Knot (*Calidris canutus*), and Semipalmated sandpipers (*Calidris pusilla*) which occur along coasts characterized by wide, well developed marshes with extensive short grass (*Pucinellia phryganodes*) zone[s] such as at North Point (NP), Big Piskwanish East (BPE), Chickney Point (CT), Swan River area (SRS) and Nowashe Creek to Lakutsaki River (PNC, and LRS)* [Figure 6-9]. *Recent observation indicates that the Hudsonian Godwit uses staging areas of James Bay to build up fat reserves for a non-stop flight to South America, a distance of at least 5000 kilometres (Morrison and Harrington, 1979).*
>
> "*Both Greater Yellowlegs (*Tringa melanoleucus*) and Lesser Yellowlegs (*Tringa favipes*) occur in large numbers on the James Bay coast, particularly in the stretch of coast between Chickney Point (CT) and the Attawapiskat area, where marshes characterized by long vegetation, especially* Hippurus vulgaris *and* Carex mackenzei *and extensive ponds occur* [Figure 6-9].

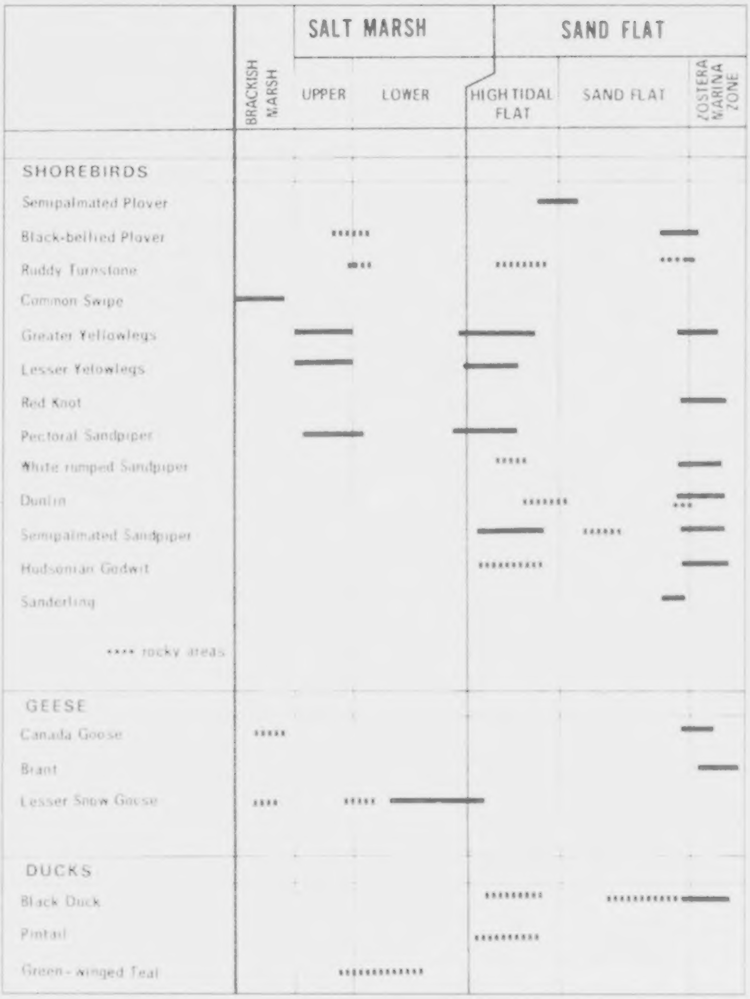

Figure 6-8. **Zones of principal habitat use for species of birds on open coastal marshes and tidal flats (from Martini et al. 1980b).**

*"Other prominent species on the coast include the Black-bellied Plover (*Pluvialis squatarola*), Golden Plover (*Pluvialis dominica*), Semipalmated Plover (*Charadrius semipalmatus*), White-rumped Sandpiper (*Calidris fuscicollis*), Least Sandpiper (*Calidris minutilla*), Dunlin (*Calidris alpina*), Sanderling (*Calidris alba*), Pectoral Sandpiper (*Calidris melanotos*), Whimbrel (*Numenius phaeopus*), Marbled Godwit (*Limosa fedoa*) and the Common Snipe (*Gallinago gallinago*).*

"Most species of shorebirds in James Bay favour well-defined zones of the marsh or flats for feeding and roosting, and resource partitioning on the basis of habitat or food type or size is apparent throughout the shorebird community [Figure 6-8]*. For instance,* Macoma balthica *is a major food resource for several species utilizing the lower intertidal zone, particularly the Hudsonian Godwit and Red Knot, which prey on medium to large size specimens. Smaller size classes of* Macoma balthica *may be taken by Dunlin, Semipalmated Sandpipers and other small Sandpipers when they use this zone. The gastropod* Hydrobia minuta *is also taken regularly by the small Sandpipers and appears to be favoured by the White-rumped Sandpiper, especially when feeding in rocky intertidal zones. Amphipods are also utilized by various species feeding in rocky areas, such as the Dunlin at North Point (NP) and Hudsonian Godwit on northwest Akimiski Island* [Figure 6-9]*. Most Semipalmated Sandpipers feed on the short grass (*Puccinellia

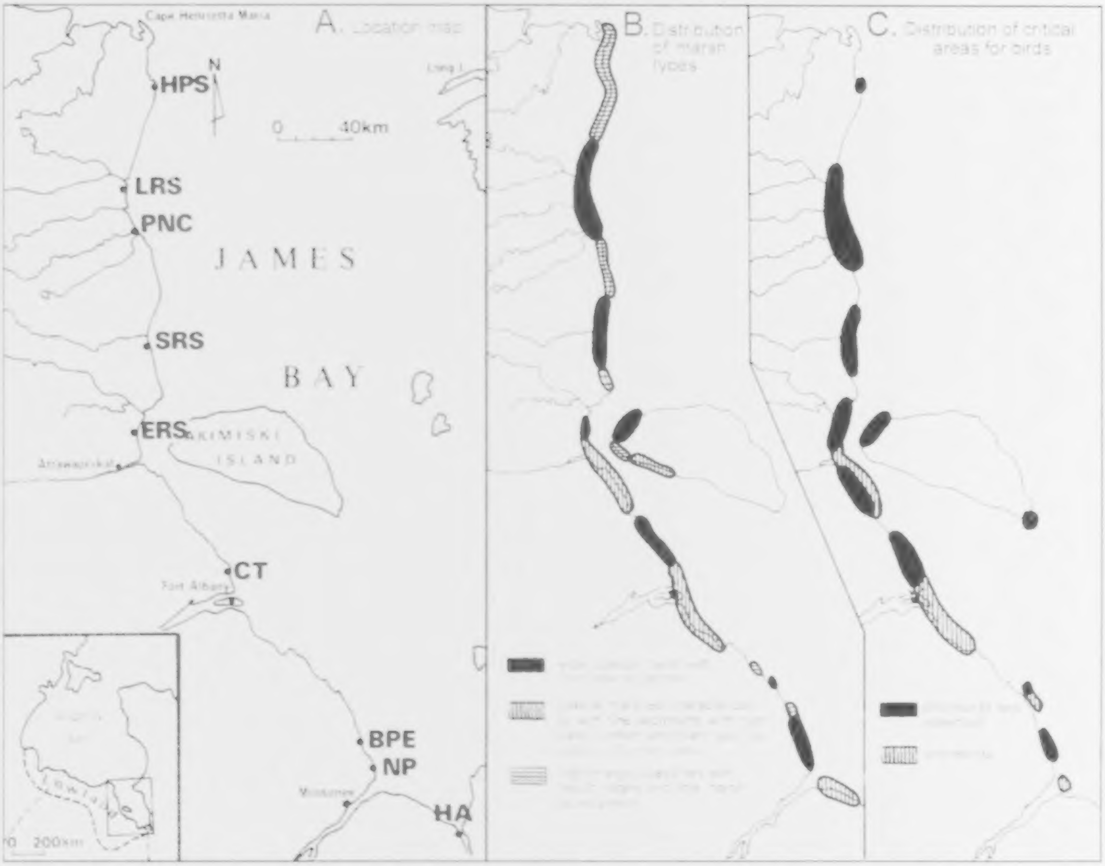

Figure 6-9. **Location map (A), distribution of marsh and coast types (B), and fall concentrations of shorebirds and waterfowl (C) on the west coast of James Bay (adapted from Martini et al. 1980b). Symbols on the location map indicate coastal transects mentioned in text, for example BPE stands for Big Piskwanish East.**

phryganodes*) salt marsh, where they prey on dipteran larvae. Lesser Yellowlegs and Ruddy Turnstones also feed on the swarms of small adult flies inhabiting the short-grass marsh. In central marsh zones, Pectoral Sandpipers and Lesser Yellowlegs are common, the latter feeding on invertebrates of ponds and sometimes on sticklebacks and small fish trapped in pools after tidal inundation.*

"Shorebirds respond sensitively to the distribution of their food resources at several levels: 1) over a wide geographical area: shorebirds numbers observed on aerial surveys are related to food resources as determined at representative transects, 2) over intermediate stretches of coastline (10 to 15 km): distribution of Semipalmated Sandpipers using short-grass saltmarsh habitat is correlated with distribution of food resources (dipteran larvae), and 3) at a local level: distribution of Semipalmated Sandpipers across various zones of the marsh on habitat transects are correlated with distribution of food resources (dipteran larvae). Studies of seasonal abundance of invertebrates indicate that migration of some species is timed to correlate with peak numbers of prey species.

"The significance of the food resources to shorebirds in James Bay lies in their use as materials which the birds convert to fat stores, essential as a food supply to enable long, non-stop flights over inhospitable "ecological barriers" such as boreal forest to the next migration stopover area. Many shorebirds make a direct flight to the Atlantic seaboard from James Bay, the Hudsonian Godwit probably to South America. While in James Bay, the birds feed intensively, distributing themselves across marsh and

intertidal areas at low tide, and gathering to rest together, often in large numbers (a few hundred to several thousand) when feeding areas are unavailable at high tide. The availability of suitable resting areas and the type of vegetation of marshes influence shorebird distribution. Areas in central or inner parts of the marsh used extensively in spring by short-legged species become unsuitable for use later in the autumn through growth of vegetation, though changing relative abundance of food resources also affects the pattern of habitat use.

"***Waterfowl**. Geese and ducks make heavy use of the James Bay coastal marshes. Canada Geese (*Branta canadensis*) breed in large numbers, though at low densities, in inland marshy areas and are numerous on the coast on migration. Lesser Snow geese (*Chen caerulescens*) are very abundant on migration and there is an extensive colony of some 50-60,000 pairs west of Cape Henrietta Maria* [Figure 6-8 and Figure 6-9]. *This colony is thought to have developed over the past 20-30 years. Brant (*Branta bernicla*) concentrate in areas of the coast where eelgrass (*Zostera marina*) is abundant in the low intertidal zone.*

*"Many species of ducks breed in inland areas and occur in large numbers on the coast on migration. Prominent species include Pintail (*Anas acuta*), Black Ducks (*Anas rubripes*), Green-winged Teal (*Anas carolinensis*), Mallard (*Anas platyrhynchos*), Widgeon (*Mareca americana*), and Scaup (*Aythya *sp.). Large rafts of Scoters (mostly Black Scoters* Melanitta nigra*) in flocks of several hundred to several thousand totalling up to about 40,000 birds are found in the northern part of James Bay from around the Swan River (SRS) to Hook Point (HPS)* [Figure 6-8 and Figure 6-9]. *Mergansers (*Mergus *sp.) and loons (*Gavia *sp.) utilize coastal waters for feeding and inland lakes and ponds for breeding.*

"Geese and ducks prefer those areas in James Bay characterized by wide coastal marshes with an emergent zone of Puccinellia phryganodes *and a variety of vegetational associations leading to fresh water inland fens* [Figure 6-8]. *Fall foods of Lesser Snow Geese in James Bay includes 40 species, of which 9 made up 90 per cent of the food items identified (Prevett* et al. *1979).* Triglochin palustris *is the most preferred and consistently selected plant. Other important foods are comprised of sedges (Cyperaceae), arrow grasses (Juncaginaceae), horsetails (Equisetaceae) and grasses (Graminae) (Prevett* et al. *1979).*

"The impact of the birds on vegetation and sediments is considerable. Geese feeding on plant shoots in the spring may leave areas of marsh uprooted and churned, and marshes in the Cape Henrietta Maria area are closely cropped to the ground after use by flocks of flightless, moulting geese and their young in the autumn. Feeding behaviour and movements of waterfowl in and out of marsh ponds influence the development of pools, the path and shape of drainage creeks, associated vegetational structure, and the thickness and character of marsh sediments."

In the James Bay region, salt marshes are developed to the greatest extent along the western shore of James Bay and at the head of the bay. Rupert Bay, and the estuary of the Hurricana River, form the eastern and southeast boundary of this salt marsh shore; to the north along the eastern James Bay coast the Shield rock is frequently exposed at the surface (in contrast to the west coast) and the coast itself is bolder and the water somewhat deeper inshore. It is also a skerry coast (see Section 3.3.3; see also chart No. 5800, Canadian Hydrographic Service 1961, updated to 1990. Dignard et al. (1991) have provided a detailed map of salt marsh distribution along the east coast of James Bay north of Rivière du Castor. While salt marshes extend along the southern coast of Hudson Bay west and north to at least Arviat, their distribution has not been documented in detail. Given the ecological importance of this habitat to geese, and the risk of its degradation by geese, salt marsh habitats along the Hudson Bay coast should be mapped in detail.

One area that has been given special attention, apart from western James Bay as a whole, is North Point (Glooschenko 1978; Clarke et al. 1982). These authors raise a point that is extremely important in northern ecology as a whole, marine and terrestrial, namely the phenomenon of seasonality in high latitudes. With respect to salt marshes, Clarke et al. (1982) write:

> *"The physicochemical properties of the intertidal and salt marsh sediments are strongly influenced by tides, and many exhibit lateral gradients associated with the frequency and duration of tidal inundation. Negative correlations between sand and silt content ($r = -0.846$, $P<0.001$), and positive correlations between clay content and elevation ($r = 0.7097$, $P<0.01$) reflect the well developed sequence of landward fining in grain size which is directly related to tidal deposition. In the salt marsh the sediments are also affected by vegetation, topography and drainage pattern. Strong seasonal changes occur in chemical properties of the sediments, but there are nonetheless well-defined trends. Elevation of the marsh is positively correlated with organic carbon content ($r = 0.613$, $P<0.01$), and negatively correlated with pH ($r = -0.780$, $P<0.001$) and electrical conductivity, although this last variable varies greatly depending on tidal inundation, precipitation and evaporation. There exist strong lateral differences in average Eh [oxidation-reduction potential] which are associated with drainage patterns. Reducing conditions are consistently recorded in marsh zones which retain standing water, have high electrical conductivities and are subject to frequent tidal inundation."*

Interactions between grazing geese and salt marsh vegetation and soils have been the subject of intensive research at La Pérouse Bay, on the southwestern coast of Hudson Bay (e.g., Jones and Hanson 1983; Jones et al. 1985; Williams et al. 1993; Jefferies et al. 1995, 2002, 2003, 2004; Abraham et al. 1996; Ganter et al. 1996; Johnson 1996a+b; Jefferies 1997, 1998, 2000; Kotanen and Jefferies 1997; Jano et al. 1998; Forbes and Jefferies 1999; Wilson et al. 1999; Chang et al. 2000, 2001; Handa and Jefferies 2000; Handa et al. 2002; Henry and Jefferies 2002; Jefferies and Rockwell 2002; Kotanen 2002; Srivistava and Jefferies 2002), in Polar Bear Provincial Park (Abraham et al. 1998), and near the McConnell River (MacInnes and Kerbes 1987; Kerbes et al. 1990; Abraham and Jefferies 1997). The primary purpose of this work has been to assess the effect of goose foraging on the salt marsh and its ability to sustain burgeoning goose populations.

At low population densities goose foraging acts to increase the primary production of intertidal salt marshes, whereas at high population densities it decreases production (Jefferies et al. 2004). The mid-continent lesser snow goose population increased sharply between 1971 and 1999, and remains large, although the implementation of spring hunts in the United States and southern Canada in 1999, and possibly declining reproductive success, appear to be limiting further growth. The high goose populations continue to damage salt marsh nesting habitats in southwestern Hudson Bay (Ganter et al. 1996; Kotanen and Jefferies 1997; Jano et al. 1998; Jefferies et al. 2002, 2003, 2004). Continued foraging has led to loss of vegetation cover and changes in species composition and soil condition in these marshes (Kerbes et al. 1990; Chang et al. 2001; Handa et al. 2002). Foraging geese remove the graminoids and short grasses by grubbing, and lyme grass (*Elymus mollis)* by shoot pulling (Ganter et al. 1996). This exposes the sediments and adversely affects reproductive success among the geese by reducing food availability (Williams et al. 1993; Jefferies et al. 1995; Ganter et al. 1996). If continued it leads to habitat abandonment. Large salt marsh swards have been converted to hypersaline (3x saltwater) mudflats that are very slow to revegetate, even in the absence of grazing, except in moist intertidal areas (Forbes and Jefferies 1999; Handa and Jefferies 2000; Jefferies and Rockwell 2002). Low soil temperatures, hypersaline conditions at the soil surface, limited nitrogen availability, and other factors interact to limit the rate of revegetation (Wilson et al. 1999). The extent of the salt marsh damage is considerable, and its progress has been followed using satellite imagery (Jano et al. 1998). This degradation also appears to decrease the species richness of aquatic invertebrate assemblages in the associated supratidal, vernal ponds (Milakovic et al. 2001). Despite damage to their nesting habitat, there is little or no evidence that a sharp decline (crash) in the goose population is imminent (Jefferies et al. 2002).

6.6 Summary

While the marine flora of the Hudson Bay marine ecosystem has been subject to detailed study in areas subject to environmental changes from hydroelectric developments or habitat degradation, it is still poorly known overall. This is particularly so for the area north and west of the Belchers, western James Bay, and Richmond Gulf; for the winter season; and for biological productivity and species distribution. Little is known of the species composition of the water column, seafloor, or sea ice; or how species distribution, abundance, or productivity change with the seasons—particularly offshore.

Hudson Bay and James Bay are remarkable in having a diverse phytoplankton, impoverished bottom flora with few seed plants, and freshwater taxa offshore in the summer--most of which are related to the presence of annual ice cover. A subpycnocline chlorophyll ***a*** maximum occurs in the offshore waters of Hudson Bay in the summer. James Bay is unusual among Canada's Arctic marine regions in having rich eelgrass beds and extensive salt marshes that provide critical habitat for migratory birds and other species. Significant degradation of salt marsh habitats has occurred along the southwestern coast of Hudson Bay as the result of foraging by the burgeoning population of nesting lesser snow geese.

7.0 INVERTEBRATES AND UROCHORDATES

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The occurrence, abundance, and ecology of invertebrates and urochordates in Hudson Bay and James Bay are not well understood. The task of surveying the region dwarfs the available research effort, precluding even geographical and phyletic coverage. Indeed, knowledge of the invertebrate species' distributions may better reflect research interests than actual species' occurrence. Most research has been conducted in summer in shallow subtidal (<50 m depth) and littoral zones, and consists of brief accounts of occurrence and/or simple listing of specific groups of organisms. Few studies have examined species abundance and community structure in relation to environmental variables such as salinity and temperature (e.g., Grenon 1982; Roff and Legendre 1986; Martini and Morrison 1987; Grainger 1988; Rochet and Grainger 1988; Runge et al. 1991; Lawrence and Baker 1995; Harvey et al. 2001); fewer still over more than one season or year (e.g., Fortier et al. 1995; Zrum 2000). Those that have run longer were typically conducted at estuaries downstream of existing or proposed hydroelectric developments, and are not representative of other nearshore or offshore habitats.

Species reported from the James Bay, Hudson Bay, Hudson Strait and Foxe Basin marine regions are listed in Appendix 2. This listing is not exhaustive. Rather, it provides a sense of the range of species that occur in the Hudson Bay marine ecosystem, or nearby. This occurrence data is summarized in Table 7-1. Because research coverage within and between regions is uneven, care must be taken in any biogeographical interpretations. Indeed, most species listed in the Appendix are likely present in the ecosystem wherever there is suitable habitat. Figures and tables that summarize the distributions of selected groups of invertebrates in other publications are listed in Table 7-2. Protozoan (single-celled) invertebrates are not discussed. Further information on Protozoa in the region is available in Cushman (1921), Wagner (1969), and Rogers et al. (1981).

At least 689 species of metazoan invertebrates and 25 species of urochordates occur in waters of the Hudson Bay marine ecosystem (Table 7-1; Appendix 2). Of these, 431 species have been reported from the James Bay marine region, which includes southeastern Hudson Bay, and 557 from the Hudson Bay marine region. The Arthropoda and Mollusca, which make up more than 50% of the known species, are the phyla best known. The Cnidaria, Bryozoa, Annelida, and Echinodermata are also well represented while the rest are each represented by few species. Each region has 18 species of urochordates, which strictly speaking are of the Phylum Chordata but are discussed here because they are invertebrates as adults (Barnes 1974). Many of these species are vital links in the food web between the primary producers and larger fish and marine mammals, but few are harvested (see Section 14.3).

7.1 ZOOGEOGRAPHY

Many of the invertebrate species in Hudson Bay and, to a lesser extent, James Bay are Arctic forms (Huntsman 1922; Osburn 1932; Clark 1937; Grainger 1968; Rochet and Grainger 1988; Harvey et al. 2001). Their presence reflects the extreme southerly penetration of Arctic waters, and the continuity of these areas with the primarily Arctic surface waters of the Canadian Arctic Archipelago and the surface of the Arctic Ocean. The invertebrate fauna of James Bay and southeastern Hudson Bay also has Atlantic and Pacific affinities, reflecting a former connection with the faunas of those oceans and illustrating the area's importance as a refugium (Fraser 1931; Squires 1967; Grainger and McSween 1976; Lubinsky 1980; Grenon 1982). Grainger (1963) cited the absence of *Calanus finmarchicus* as evidence that there is now no direct penetration of Atlantic surface waters into Hudson-James Bay. However, this species has since been reported at the Churchill River estuary (Baker et al. 1994). Estuarine species are distributed throughout James Bay and southeastern Hudson Bay, but are present in the highest density in or near river mouths. Freshwater species do not survive far from the rivers, and Arctic marine species become dominant as distance from the large estuaries increases.

7.2 INVERTEBRATE COMMUNITIES

Few benthic species inhabit the intertidal zone of James Bay or Hudson Bay on a permanent basis, likely due to ice scour, which can extend to a depth of 5 m (Dadswell 1974), and to freezing (Dale et al. 1989) (Figure 7-1.). Invertebrates such as clams, mussels, snails, barnacles, worms, sea anemones, amphipods, and sea squirts occupy the intertidal zone during the open water season. Most benthic invertebrates, including the echinoderms, sea spiders, most polychaetes, clams and snails, shrimps and crabs, hydroids and bryozoans live below the ice scour zone. Seafloor photographs taken during the 1961 cruise of the M.V Theta at a depth of 55 m show brittle stars, anemones, a shrimp, and a worm on the fine substrate of Omarolluk Sound in the Belchers (Barber et al. 1981). Central Hudson Bay supports a meager fauna (Fraser 1931; Willey 1931; Wagner 1969; Roff and Legendre 1986) with echinoderms--especially brittle stars, polychaetes, sea anemones and decapods being predominant (Grainger 1968; Barber et al. 1981).

Important benthic species in the Eastmain River estuary include the pelecypods *Macoma balthica* and *Mytilus edulis*, the gastropods *Cylichna alba* and *Margarites olivaceus*, the polychaetes *Terebellides stroemi* and *Aglaophamus neotenus*--the latter previously known only from the Atlantic coast, the cumacean *Diastylis rathkei*, and the amphipods *Atylus carinatus* and *Onisimus littoralis* (Grenon 1982). Distribution of the benthic organisms

Table 7-1. **A comparison of the number[1] of invertebrate and urochordate species reported from the James Bay (including southeastern Hudson Bay=JB), Hudson Bay (HB), Hudson Strait (HS), and Foxe Basin (FB) marine regions (Figure 1-1). This comparison is based on the partial species list found in Appendix 2.**

PHYLUM/Group	Common name	JB	HB	HS	FB	JB, HB, HS or FB	JB, HB, HS&FB	Only JB	Only HB	JB or HB
ANNELIDA										
Oligochaeta		0	19	0	0	19	0	0	19	19
Polychaeta	bristle worms	55	80	86	35	133	9	12	23	102
ARTHROPODA										
Amphipoda	scuds/side swimmers	83	91	157	101	209	35	10	11	120
Cirripedia	barnacles	4	3	4	5	6	3	1	0	4
Copepoda		47	52	15	4	77	2	22	27	74
Cumacea		11	8	9	9	20	3	5	2	14
Decapoda	shrimps/crabs	13	14	18	12	20	10	0	1	15
Euphausiacea	krill	1	2	2	1	4	0	0	0	2
Isopoda		4	5	9	8	15	2	1	2	7
Mysidacea	opossum shrimps	4	4	7	1	7	1	0	0	5
Nebaliacea		1	0	1	1	1	0	0	0	1
Ostracoda	seed spiders	4	3	4	1	6	0	2	0	5
Pycnogonida	sea spiders	3	6	9	13	16	3	0	2	6
Tanaidacea		4	0	0	0	4	0	4	0	4
ASCHELMINTHES										
Nematoda	round worms/thread worms	1	1	1	1	1	1	0	0	1
BRACHIOPODA	lamp shells	2	2	2	2	2	2	0	0	2
BRYOZOA	moss animals	15	46	83	39	94	6	1	10	53
CHAETOGNATHA	arrow worms	2	3	3	0	4	0	1	0	4
CHORDATA: Urochordata	tunicates									
Ascidiacea	sea squirts	15	16	24	20	30	8	3	1	22
Larvacea		3	2	2	2	3	0	1	0	3
CNIDARIA										
Anthozoa	sea anemones/soft corals	9	10	8	7	18	2	4	3	14
Hydrozoa	hydroids/medusae	28	46	52	26	75	8	4	10	55
Scyphozoa	jellyfish	1	1	1	0	1	0	0	0	2
CTENOPHORA	comb jellies	2	2	2	0	3	0	0	1	3
ECHINODERMATA										
Asteroidea	sea stars	9	17	15	14	20	7	1	3	18
Crinoidea	sea lilies/feather stars	1	1	1	1	1	1	0	0	1
Echinoidea	sea urchins	1	1	1	1	1	1	0	0	1
Holothuroidea	sea cucumbers	5	6	5	6	8	3	0	2	8
Ophiuroidea	brittle stars	9	10	11	9	13	7	0	1	11
MOLLUSCA										
Cephalopoda	squids/octopus	0	0	2	1	3	0	0	0	0
Gastropoda	snails	33	51	53	53	91	12	4	18	61
Pelecypoda	clams/mussels/scallops	47	42	43	28	65	23	9	6	54
Polyplacophora	chitons	2	3	2	2	3	2	0	1	3
Scaphopoda	tooth shells/tusk shells	0	1	0	0	1	0	0	1	1
NEMERTEA	proboscis worms/ribbon worms	1	1	1	1	1	0	0	0	1
PHORONIDA		0	1	0	0	1	0	0	1	1
PORIFERA	sponges	9	1	9	1	20	0	9	1	10
PRIAPULIDA	penis worms	1	2	2	1	3	1	0	1	2
SIPUNCULA	peanut worms	1	4	4	1	6	0	0	2	5
	Total:	431	557	648	407	1003	152	94	149	714

[1] Totals include mollusc records based on recently dead animals and/or empty shells. Organisms identified only to genus were included only if the genus was not otherwise reported from the region. They were included in the species counts for each region, but were only included in the overall species totals if no organisms of that genera had been identified to species.

Table 7-2. Some published distributions of selected invertebrates in James Bay and Hudson Bay.

Author/Year	Invertebrate group	Table/Figure	Page(s)
Kerswill 1940	Pteropoda	Fig. 4	29
Dunbar 1954	Amphipoda	Fig. 41+42	792-793
Dunbar 1962	Chaetognatha	Fig. 1	78
Grainger 1963	Copepoda	Fig. 6	78
Hedgepeth 1963	Pycnogonida	Fig.1-3 + 11	1316-1318, 1344
Johnson 1964	Isopoda	Fig. 6	86
Trason 1964	Ascidacea	Table 3	1510-1513
Grainger 1966	Asteroidea	Fig. 47-62	21-49
Squires 1967	Decapoda	Table 2; Fig. 3-7	1879-81, 1883-93
Grainger 1968	Copepoda/ Amphipoda/ Euphasiacea/Ascidiacea	Fig. 1	355
Pelletier et al. 1968	Mollusca/ Brachiopoda/ Cirripedia/Echinoidea	Table 2	573-577
Powell 1968	Ectoprocta	Fig. 2-9	2283-2310
Wagner 1969	Gastropoda/Pelecypoda	Table 6; Fig. 3	24, 25, 27
Calder 1970	Hydrozoa	Text	1503-1547
Macpherson 1971	Gastropoda	Fig. 2-54	6-122
Calder 1972	Hydrozoa	Text	218-226
Dadswell 1974	Polychaeta/ Amphipoda/ Mysidacea/ Gastropoda/ Pelecypoda/ Asteroidea	Table 1	479
Grainger and McSween 1976	Copepoda	Fig. 13-34	27-48
Lubinsky 1980	Pelecypoda	Fig. 1-42	74-94
Rogers et al. 1981	Protozoa	Fig. 1, Table 1	2361
Grenon 1982	Polychaeta/Pelecypoda	Fig. 3-5	797-799
Martini and Morrison 1987	Gastropoda/Pelecypoda	Fig. 3 + 4	52-55
Rochet and Grainger 1988	Copepoda/ Amphipoda/ Hydrozoa/Gastropoda/ Chaetognatha/Cirripedia	Tables 1 + 3, Fig. 4	1628-9
Dunbar 1988	Copepoda/ Euphasiacea/ Amphipoda	Fig. 15-20	not numbered
Grainger 1988	All groups	Table 1	134
Atkinson and Wacasey 1989	All groups	Tables 39-45, 51-79, 82-87, 93-102, 128	45-48, 52-67, 70-74, 79-83, 100.
Baker 1989	All groups	Fig. 24-39; Appendices 1a-2c	143-158, 169-179
Squires 1990	Decapoda	Fig. 90 ff	172ff
Morin 1991	All groups	Table 5	21
Ponton and Fortier 1992	Copepoda/ Chaetognatha	Table 2	218
Baker et al. 1993	All groups	Tables 5 + 7	40, 41, 43
Byers 1993	All groups	Taxanomic List	3-6
Baker et al. 1994	All groups	Appendices 3-6	74-81
Lambert and Prefontaine 1995	Pelecypoda	Figure 1	24
Lawrence and Baker 1995	All groups	Table 4+7	17-19, 22-24
Baker 1996	All groups	Appendices 3a+b	58-63
Simard et al. 1996	All groups	Annex 10	141-189
Horne 1997	All groups	Tables 4+5, Appendices A-2 + A-3	29-34, 63-64
Siferd et al. 1997	Amphipoda	Table 1	18
Horne and Bretecher 1998	All groups	Tables 4+5, Appendices A-2 + A-3	29-34, 65-68
Zrum 1999	All groups	Tables A-2 and A-3	64-71
Zrum 2000	All groups	Table 4+5, Appendix 1, Table A2-2 +A2-3	31-38, 57-62, 67-74

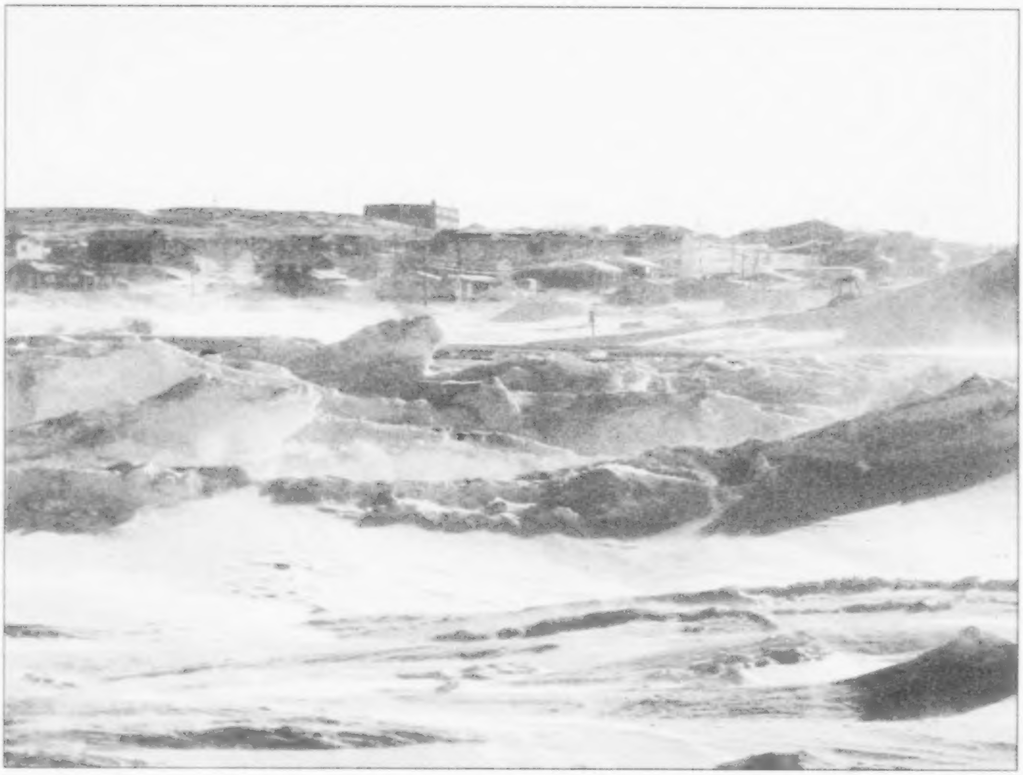

Figure 7-1. Sea ice turned on edge and scouring the shoreline and harbour bottom at Rankin Inlet (photo credit D.B. Stewart).

was positively related to the salinity gradient and the quantity of organic matter in the sediments. The dominant species of each group are very versatile in their occupation of different sediment types. Density of the benthic fauna in the brackish zone of the estuary was very low compared with freshwater or marine areas; the marine zone also had the most diverse benthic fauna.

The pelagic zone is characterized by comb jellies, arrow worms, copepods and amphipods, euphausids, and the pelagic sea butterflies. Grainger and McSween (1976) described the marine zooplankton of James Bay as being of "*moderate quantity and fairly high diversity for northern waters, reflecting the range of habitat provided by the 2-layer estuarine structure*". The ratios of species groups characteristic of fresh, brackish, and marine water vary over time, reflecting seasonal pulsations in the surface brackish water and saltier bottom water within the bay (Grainger and McSween 1976).

Four distinct species assemblages of zooplankton were identified along a sampling transect from the mouth of James Bay to eastern Hudson Strait in early September 1993 (Harvey et al. 2001; Figure 7-2 and Figure 7-3). Group A in Hudson Bay south of the Belcher Islands and further offshore west of the Sleeper Islands was strongly influenced by freshwater runoff entering James Bay and southern Hudson Bay. The circulation was typically estuarine with a relatively warm (8.5°C), dilute (24.5 ppt [≈psu]) surface layer 10-15 m deep, overlaying a colder (<1.0 °C), more saline (~31.0 ppt) deep layer. Chlorophyll ***a*** values were higher in the surface layer (>1.0 $\mu g{\cdot}L^{-1}$), but low relative to other areas. The zooplankton community in this area was characterized by the presence of two euryhaline copepod species (*Acartia longiremis* and *Centropages hamatus*) (Figure 7-4), with an integrated biomass ranging from 0.9 to 2.7 g $DM{\cdot}m^{-2}$. Group B, along the east coast of Hudson Bay, and Group C, at the northeast exit to Hudson Bay and in western Hudson Strait, were characterized by a typically Arctic fauna, related to the cyclonic circulation in central Hudson Bay. The water column in these areas was strongly stratified,

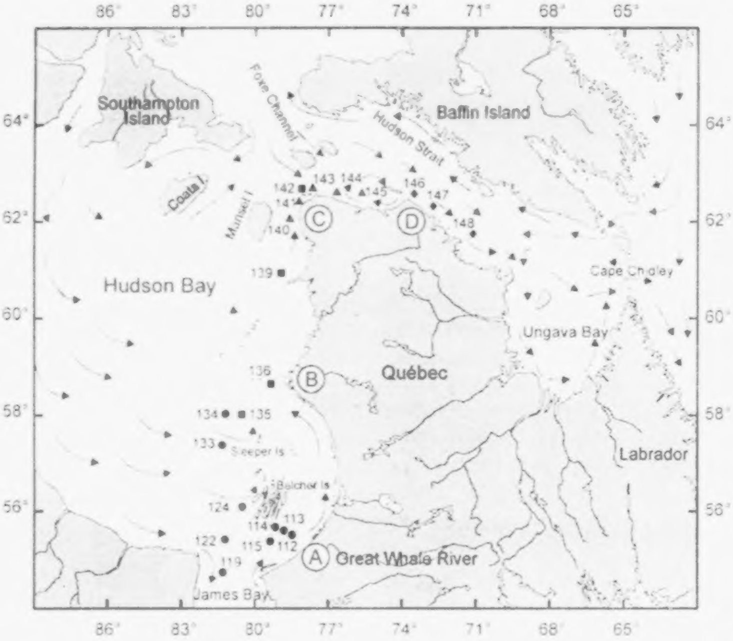

Figure 7-2. **Sampling sites for zooplankton in Hudson Bay and Hudson Strait in September 1993, with arrows showing the general pattern of surface circulation and symbols the positions of four distinct groups of stations which were determined using cluster analysis (● group A; ■ group B, ▲ group C, ◆group D) (from Harvey et al. 2001, p. 483).**

with a mixed surface layer that was deeper in the Bay (20 m) than in the Strait (15 m). Within this layer, the temperature (6-7°C) and salinity (27-28 psu) were relatively constant and chlorophyll ***a*** values were very low (<0.5 $\mu g \cdot L^{-1}$). A strong subpycnocline Chlorophyll ***a*** maximum was also characteristic of these areas (see also Harvey et al. 1997). The integrated biomass of the Group B and C stations varied from 1.6 and 9.3 g $DM \cdot m^{-2}$. Zooplankton species that contributed most to the segregation of Group B were the pteropods *Clione limacina* and *Spiratella helicina*, some unidentified crustaceans, the amphipods *Themisto libellula* and *T. abyssorum*, the euphasid *Thysanoessa rachii*, and the copepods *Calanus hyperboreus*, *Metridia longa* and *C. glacialis/C. finmarchicus* (species combined). The same species also contributed to the separation of Group C, but were typically more abundant and, in some cases such as *M. longa*, had a higher relative abundance. Group D, in central Hudson Strait, was characterized by a much higher zooplankton biomass, and by the greater abundance of the large herbivorous copepod *C. glacialis/C. finmarchicus* and of some unidentified euphasiids. The water column had a weaker stratification in the upper 40 m, with the coldest (~2.6°C) and most saline (~31 psu) surface waters encountered on the transect, and much higher chlorophyll ***a*** concentrations (~220 $mg \cdot m^{-2}$) throughout the water column. The large-scale spatial structure of these assemblages corresponded closely to that observed in phytoplankton along the same transect (see also Harvey et al. 1997). This structure suggests that they are strongly influenced by local hydrodynamic features which, through their action on surface water temperature, salinity, stratification and mixing conditions, lead to spatial differentiation of the phytoplankton and zooplankton communities (Harvey et al. 2001).

The ice fauna is not as well known as the ice flora. In April 1983, offshore the mouth of Grande rivière de la Baleine, invertebrates living in the lower 3 cm of the sea ice consisted largely of planktonic nematodes, rotifers, ciliates, and copepods--in order of abundance (Hsiao et al. 1984; Grainger 1988). The sea ice fauna was generally denser but less diverse than the zooplankton occuring beneath the ice, both within and outside the river plume (Hsiao et al. 1984). The abundance was positively related to salinity, and to the presence of sea-ice microflora (Grainger 1988; Tourangeau 1989). Because the standing stock of sea-ice fauna is greater under marine conditions, it could be decimated by a winter expansion of the freshwater plume (Grainger 1988).

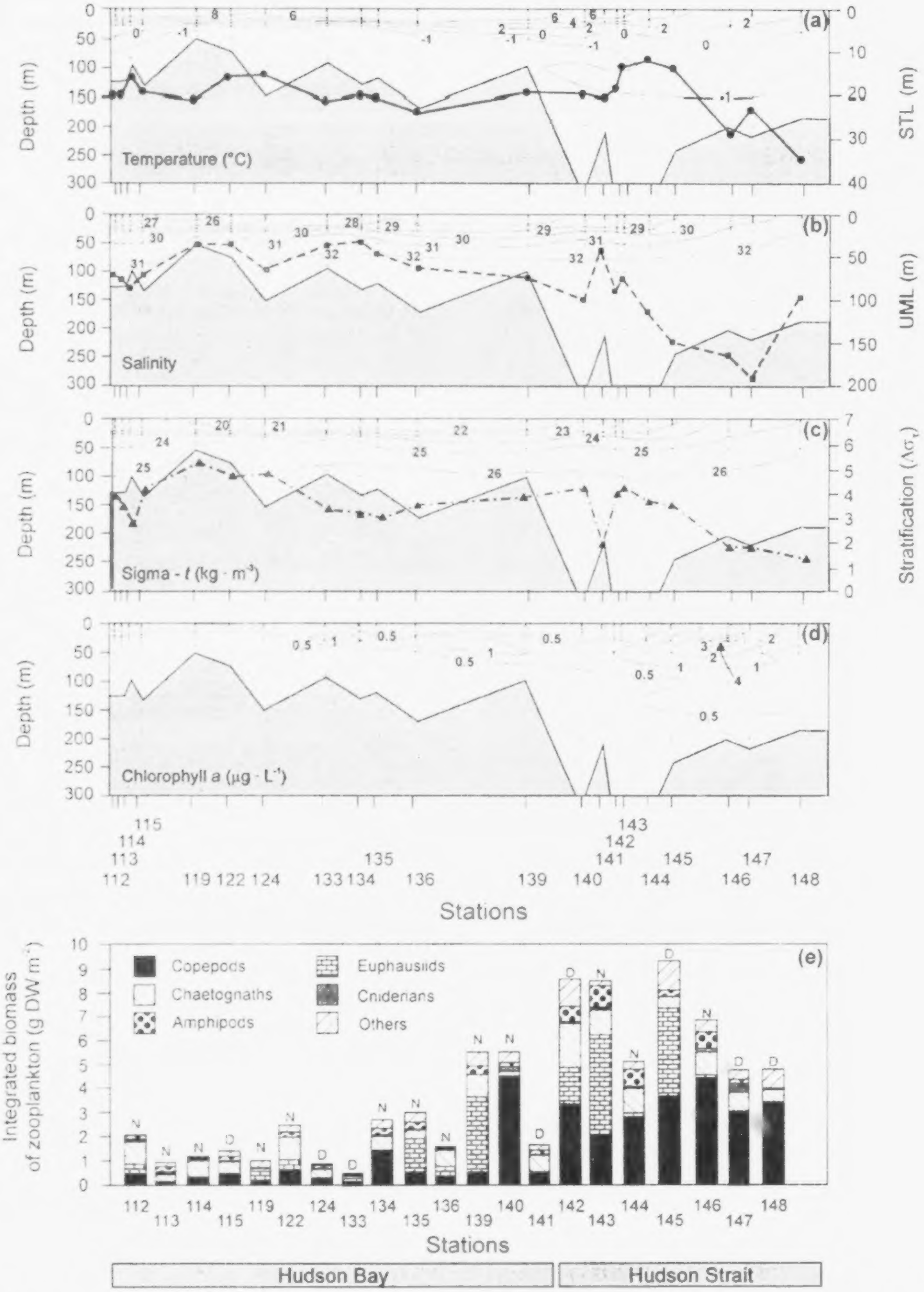

Figure 7-3. Vertical distribution of temperature, salinity (psu), σ_t, chlorophyll *a*, and the integrated biomass of zooplankton at sampling stations (see Figure 7-2) in Hudson Bay and Hudson Strait (D=day; N=night), with the depth of the surface thermal layer (STL; —), the depth of the upper mixed layer (UML; - - -), and the index of stratification ($\Delta\sigma_t$; — • —) shown for each site (from Harvey et al. 2001, p. 486).

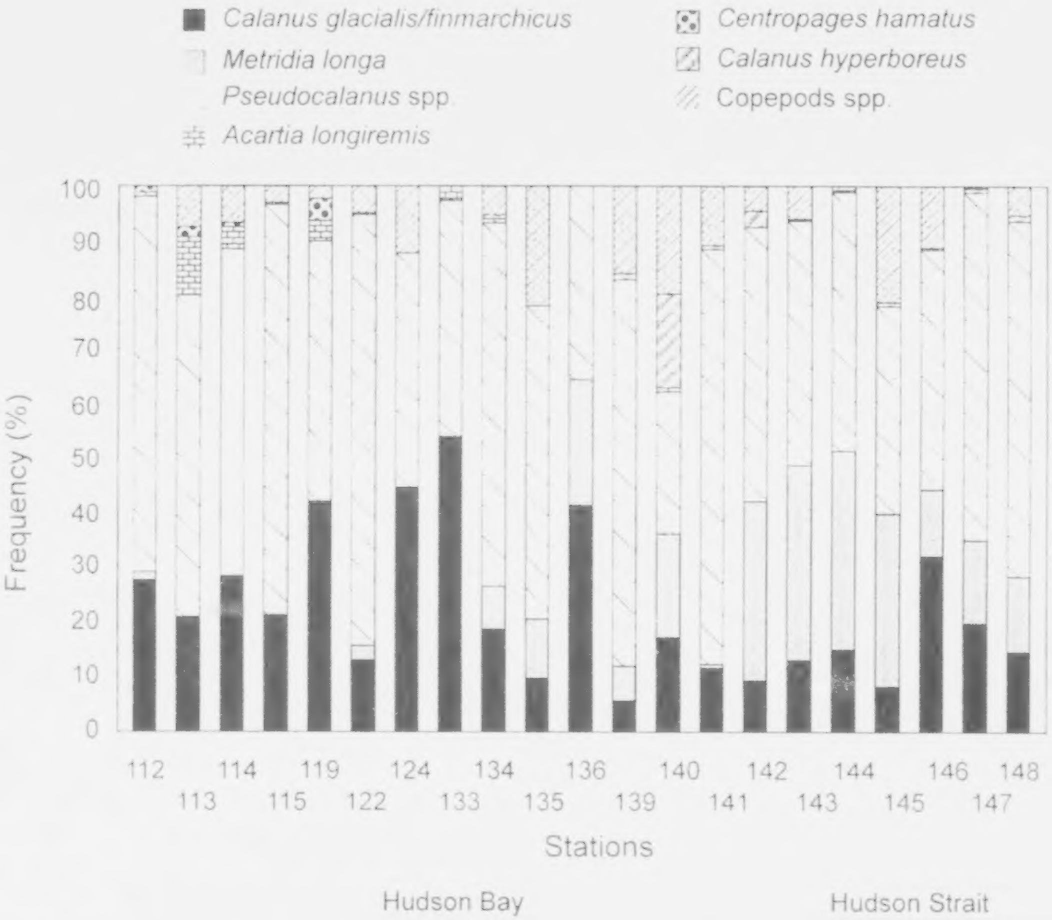

Figure 7-4. **Relative frequency of occurrence of the most numerous copepod species along the sampling transect in Hudson Bay and Hudson Strait (from Harvey et al. 2001, p. 489).**

Feeding activity increased significantly in mid-May, after the start of ice melt when ice algae were released in large quantities into the water column (Runge et al. 1991). Egg production was negligible during the ice algal bloom but by June had increased about two orders of magnitude. Major sources of food energy for copepod production during this period are sedimenting ice algae (during and immediately after the bloom at the ice-water interface), and diatoms seeded from the interfacial layer and actively growing in the water column in late May and June. The availability of copepod nauplii varies substantially between years, both in magnitude and timing, and may be related more to the dynamics of cyclopoid copepods during the previous winter than to the timing of the spring algal blooms (Fortier et al. 1995). These changes have a direct impact on the feeding success of larval Arctic cod and sand lance that hatch several weeks before ice break-up and feed heavily on the copepod nauplii in mid-June (Drolet et al. 1991; Ponton and Fortier 1992; Fortier et al. 1995, 1996).

Copepods, *Sagitta elegans*, and jellyfish were much more abundant in the deeper marine layer off Grande rivière de la Baleine in May 1989, than in the brackish under-ice plume (Figure 7-5)(Ponton and Fortier 1992). With the exception of *S. elegans*, which accumulate at the pycnocline at night, the vertical distributions of these zooplankters differ little between day and night. By affecting both prey density and light, plume thickness is an important determinant of feeding success by larval fishes (Fortier et al. 1995, 1996; see also Section 8.3).

Hudon (1994) found chaetognaths (*Sagitta elegans* and *S. maxima*), euphausiid and decapod larvae, cnidarians (*Aglanthe digitale*), and pterepods (*Spiratella helicina*) to be the most abundant marine invertebrates taken in 500 µm mesh plankton nets beneath the Grande riviere de la Baleine plume during and after break-up. Chaetognaths were by far the most abundant group, with up to 8 individuals•m^{-3}. These exclusively marine species are prevented from preying upon the fish and insect larvae in the overlying plume as long as stratified conditions prevail.

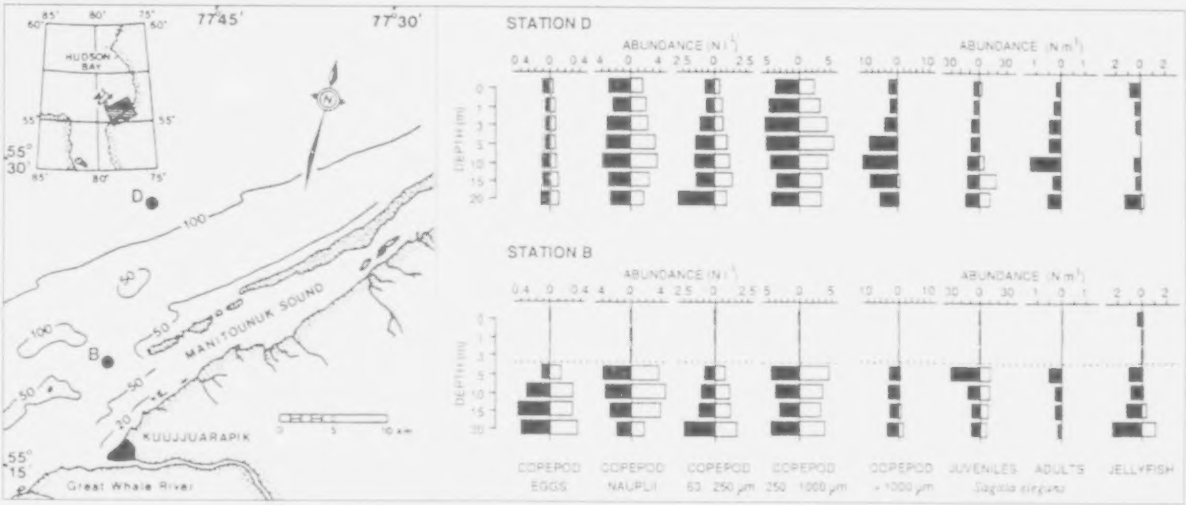

Figure 7-5. **Vertical distribution of zooplankton taxa by night (black histograms, n = 6 profiles) and day (open histograms, n=11 profiles) at stations D and B offshore Kuujjuarapik in May 1989 (from Ponton and Fortier 1992, p. 216+219). Dotted line for Station B indicates the depth of the sharp pycnocline between the brackish surface layer and deep marine layer. Note the compressed vertical scale.**

7.2.1 Phyla Porifera, Ctenophora, Nemertea, Brachiopoda, Phoronida, Priapulida, Nematoda, Sipuncula and Chaetognatha

These phyla are not well known in Hudson Bay and James Bay, and are generally represented by few species with unknown distributions. The exception is *Sagitta elegans*, a chaetognath or arrow worm that is common and widely distributed in Hudson Bay (Willey 1931; Dunbar 1962; Baker 1989). It was the most abundant species in most samples taken from eastern Hudson Bay and Hudson Strait during August 1993 (Simard et al. 1996). It was particularly abundant between the depths of 10 and 70 m, sometimes with counts of over 30 individuals•m^{-3}. Sponges have been collected from the Hudson Bay marine region but not identified (Barber et al. 1981). Species have been identified from Richmond Gulf (Dendy and Frederick 1922) and northern Hudson Bay (Wagner 1969). Three ctenophores have been reported; all common Arctic species (Willey 1931; Gaston et al. 1985; Percy and Fife 1985) (Figure 7-6). Mikhail and Welch (1989) reported a phoronid in the diet of Greenland cod from Saqvaqjuac Inlet. The specimen was not identified to genus, but Barnes (1974) indicates that the phylum consists of only 2 genera, *Phoronis* and *Phoronopsis*.

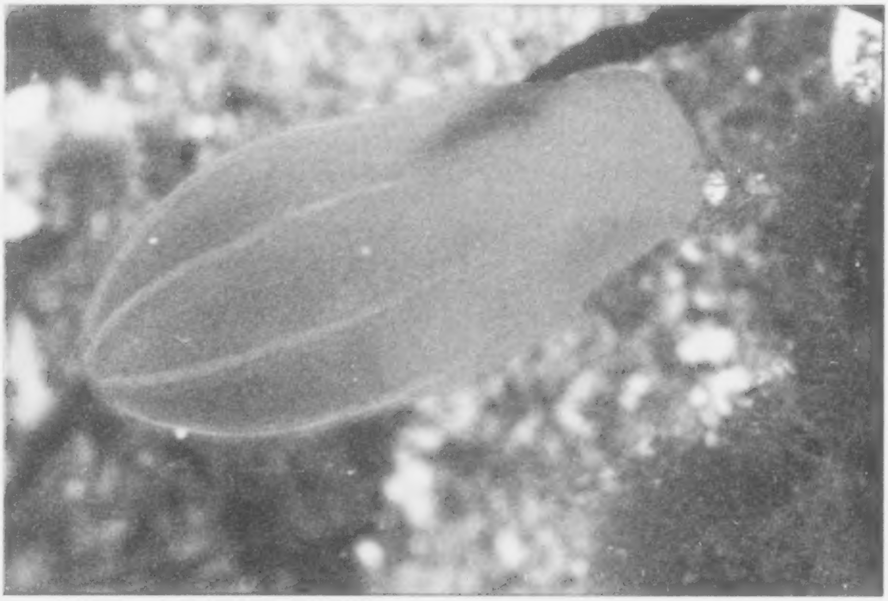

Figure 7-6. **Ctenophore *Beroe cucumis* near Churchill, Manitoba (photo credit D. Rudkin, Royal Ontario Museum, all rights reserved)**

7.2.2 Phylum Cnidaria (anemones, soft corals, hydroids, medusae, jellyfish)

The Cnidarians are mainly benthic invertebrates represented by at least 71 species in the Hudson Bay marine ecosystem, 38 of which occur in the James Bay marine region and 57 in the Hudson Bay marine region (Table 7-1, Appendix 2). The majority of these species are hydroids, which are restricted to rocky substrates. They are seldom found over the greater part of James Bay or Hudson Bay, where a muddy bottom occurs, but are locally common. They are very common in Richmond Gulf, where Fraser (1922, 1931) collected 17 species in a single dredge sample. The common Arctic medusae *Aeginopsis laurenti* and *Aglantha digitale* are widespread in Hudson and James bays. The sea anemone, *Tealiopsis stella* is found in the intertidal zone and in shallow water in southeastern Hudson Bay (Verrill 1922); anemones photographed on the bottom of southeastern Hudson Bay have not been identified (Grainger 1968; Barber et al. 1981). The group is also represented in deep water by the octocoral *Gersemia rubiformis* (Verrill 1922; Barber et al. 1981). The Scyphozoa are represented only by *Cyanea capillata*, the largest known jellyfish, which has been collected from southwestern Hudson Bay near the Churchill and Nelson estuaries (Baker et al. 1994; Lawrence and Baker 1995; Baker 1996; Zrum 2000; G. Young, MB Museum, pers. comm.), and likely (*Cyanea* sp.) near Cape Fullerton (Bigelow 1920) and southeast of the Belcher Islands (Simard et al. 1996) (Figure 7-7).

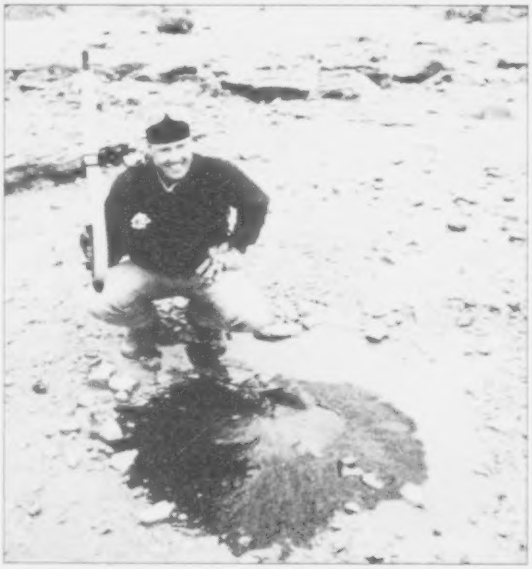

Figure 7-7. **A large jellyfish (*Cyanea capillata*) stranded on the tidal flats in polar bear country near Churchill, Manitoba (photo credit G. Young, Manitoba Museum).**

7.2.3 Phylum Bryozoa (moss animals)

Bryozoans, or moss animals, are common benthic invertebrates in Hudson Bay and James Bay. Fifty-three species have been reported from the Hudson Bay marine ecosystem (Table 7-1; Appendix 2). Of these, 46 species have been reported from the Hudson Bay marine region, mainly along the western coast, the coasts of the northern islands and in the southeastern portion of the bay (Osburn 1932, 1936; Powell 1968; Baker 1989; Baker et al. 1994; Lawrence and Baker 1995); and 15 species have been reported from James Bay and southeastern Hudson Bay (Osburn 1932; Powell 1968). Bryozoans predominate at depths greater than 30 m and prefer hard substrates (Powell 1968) that occur in a band from the northwest coast down to the southeastern part of the bay (Pelletier et al. 1968). Osburn (1932) found 20 species of byrozoans attached to large algae, mostly *Laminaria* sp., that had washed up on beaches near Churchill. Common species of bryozoans include *Cystisella saccata*, *Myriapora subgracila*, *Celleporella* (*Hippothoa*) *hyalina*, and the deepwater form *Eucratea loricata*, which occurs down to 160 m (Osburn 1932; Powell 1968).

7.2.4 Phylum Annelida (bristle worms)

Polychaete annelids, or bristle worms, are benthic invertebrates that prefer mud bottoms and occur in shallow to deep water, often in large numbers. Berkeley and Berkeley (1943) reported 57 species from Hudson Bay, but many of these species are likely from Hudson Strait and Ungava Bay. At least 102 species have been identified from Hudson Bay marine ecosystem but otherwise little is known about them (Table 7-1). Of these, 80 occur in the Hudson Bay marine region and 55 in the James Bay marine region. Of the latter, 23 have not been reported from Hudson Bay, Foxe Basin, or Hudson Strait (Table 7-1). *Aglaophomus neotenus*, the most abundant polychaete in the Eastmain River estuary, was previously known only from estuaries along the Atlantic coast (Grenon 1982), and may be a relict species. Baker (1989) found *Manayunkia aestuarina* to be abundant in the mud flats of the Nelson River estuary. In central Hudson Bay worm tracks, or *lebensspuren*, are conspicuous in the fine bottom sediments at station 130 of Barber et al. (1981). They identify *Onuphis* sp., a mobile tube dweller. From western Hudson Bay, Wagner (1969) identified *Cistenides* sp., the only species recorded from the area during the cruise of the CSS Hudson in 1965.

7.2.5 Phylum Arthropoda

Arthropods are represented in the Hudson Bay marine ecosytem by 6 species of pycnogonids and 251 species of crustaceans. Based on their distribution in relation to salinity and temperature they can be grouped into arctic, estuarine, and freshwater species. At least 6 species of pycnogonids and 182 species of crustaceans occur in the Hudson Bay marine region and 3 pycnogonid and 176 crustacean species in the James Bay marine region. Most are typical Arctic species with widespread distributions, and occupy a wide variety of habitats. The pycnogonids or sea spiders are small benthic carnivores, while the crustaceans may be planktonic, pelagic, or benthic in habit and range in feeding types from carnivores to filter-feeders. Many large and small species of crustaceans are important prey for larger animals including fish, birds, and mammals (e.g., Shoemaker 1926; Stephensen 1937; McLaren 1958b; Smith 1981; Gaston et al. 1985). None is known to be present in commercially exploitable quantities.

The amphipods are a group of laterally compressed crustaceans that can be benthic, pelagic, or sympagic (ice associated) in habit. They are widespread in Hudson Bay and James Bay. Amphipods can be voracious scavengers and congregate in large numbers in tidal pools to devour dead animals, functioning as the sea's "garbage disposal unit". Pelagic species such as *Themisto libellula* and *T. abyssorum* are common and numerous in samples taken offshore in eastern Hudson Bay; *T. libellula* at depths of 10-100 m and *T. abyssorum* from the surface to >200 m (Simard et al. 1996; Harvey et al. 2001).

Amphipods inhabit the underside of sea ice (sympagic) in the Chesterfield Inlet area of northwestern Hudson Bay (Siferd et al. 1997), and may also be present in shallow coastal areas around Hudson Bay and James

Bay. Twelve species were collected from the Chesterfield Inlet area, the most common being *Ischyrocercus anguipes*, *Pontogenia inermis*, *Apherusa megalops*, and *Weyprechtia pinguis*. Amphipods colonized the sea ice shortly after it formed, and their abundance was strongly affected by the underlying water depth. It increased gradually from shallow water to about 20 m, with a maximum recorded abundance of 1367 m^{-2}, and then decreased rapidly to near zero after 50 m. Ice amphipods followed the same pattern in seasonal abundance as the ice algae, increasing steadily from March through the 3rd week of April and then declining. Locally their grazing can significantly reduce the inshore ice algal biomass, but this is limited to the shallowest areas where amphipods are present in the greatest numbers.

Copepods are abundant and widespread in Hudson Bay but variable in their distribution, abundance, and species composition. Roff and Legendre (1986) found that the biomass of Copepoda decreased towards the centre of the bay. Copepods are important foods for fish, birds, and baleen whales. The substantial bowhead population that once summered in northeastern Hudson Bay suggests that dense concentrations of Copepoda may be present in that area, while the apparent historical absence of a substantial bowhead population suggests that dense concentrations of copepods may be uncommon in James Bay and southeastern Hudson Bay.

During the open water season in southeastern Hudson Bay:

> *"...the greatest copepod densities, consisting mainly of euryhaline species (*Acartia*, etc.) were found above the pycnocline near shore, where phytoplankton was probably present in its greatest density. Arctic species, in low overall numbers at the same locations, were few above the pycnocline, probably excluded by the low salinity. At stations farther from shore, the greatest concentration of copepods comprised arctic species (*Calanus*, etc.), found for the most part below the pycnocline depth, where the subsurface chlorophyll maximum was reported to occur." (Rochet and Grainger 1988)*

Freshwater species (e.g., *Diaptomus*) are restricted to the river mouths. Harvey et al. (2001) observed similar patterns in copepod abundance in southeastern and eastern Hudson Bay. In April 1983, the most abundant copepods in the sea ice were *Harpacticus superflexus*, followed by *Halectinosoma* sp., and then *Tisbe furcata* (Grainger 1988).

Twenty-two species of copepods found in James Bay have not yet been reported from Hudson Bay, Foxe Basin or Hudson Strait (Table 7-1; Appendix 2). The disjunct distributions of species such as *Monstrilla dubia* illustrate the special nature of the James Bay marine region within Arctic Canada. They show that it supports an estuarine fauna atypical of northern Canadian marine waters; that the fauna has strong Atlantic and Pacific affinities; and that this region remains as a refuge, reflecting a former connection with the faunas of the North Pacific-Chukchi-Beaufort Sea region and of the North Atlantic (Grainger and McSween 1988). The continued existence of these isolated, relict populations is precarious and depends upon the persistence of estuarine conditions and higher surface temperatures in the James Bay marine region.

Decapods are the largest of the crustaceans, and include the shrimps and crabs which are widespread in Hudson Bay and James Bay (Squires 1967). An exploratory commercial survey of northeastern Hudson Bay found their abundance to be low (M. Allard, Makivik Corp., Lachine, pers. comm.), however, they are important prey for ringed seal (McLaren 1958), bearded seal (Stephensen 1937; Smith 1981), sea birds (Gaston et al. 1985) and fish (Vladykov 1933; Mikhail and Welch 1989). Most of the species in James Bay marine region, including the brachyuran crab *Hyas coarctatus*, are smaller than their counterparts in other Arctic and Subarctic areas. The Inuit of this region do not commonly utilize decapods.

The euphausiids *Thysanoessa raschii* and *Furcillia* sp. are common and widespread. These pelagic, shrimp-like crustaceans are also known as krill. *T. raschii* are eaten by seabirds (Gaston et al. 1986). In September 1993, *Furcillia* sp. was common from the surface to a depth of about 50 m (Simard et al. 1996). It was found at concentrations of up to 3.5 individuals·m^{-3} in southeastern Hudson Bay, and can be very abundant in

Hudson Strait (170 individuals·m^{-3}). Pelagic amphipods (Hypiriidea) such as *Themisto* spp. can rival the euphausiids in abundance and pelagic significance.

The distributions of other groups of crustaceans that occur in Hudson Bay and James Bay, including the Cirripedia, Cumacea, Isopoda, Mysidacea, and Ostracoda are not well known. The Branchiopoda are only found near river mouths near river mouths in James Bay and southeastern Hudson Bay. They are not listed in Table 7-1 or Appendix 2.

7.2.6 Phylum Mollusca

There are at least 119 species of molluscs, representing 5 classes, in the Hudson Bay marine ecosystem (Table 7-1). Of these, 97 occur in the Hudson Bay marine region, and 82 occur in the James Bay marine region. Of the latter, 13 have not been reported from Hudson Bay, Hudson Strait, or Foxe Basin. Gastropods and pelecypods (bivalves) account for almost all of the species, and are found in all types of habitat ranging from the intertidal zone to the deeper areas of Hudson Bay. Most of the adult molluscs are benthic and uncommon in central Hudson Bay, where there are fewer gastropods than pelecypods (Macpherson 1971; Lubinsky 1980; Barber et al. 1981).

Ice scour may also limit molluscs along the shallow west coast of Hudson Bay (Macpherson 1971) but Martini and Morrison (1987) found the pelecypod *Macoma balthica* to be widely distributed and abundant along the west coast of James Bay in summer--primarily in the lower tidal flats. While the species is able to tolerate a wide range of salinities, it may be less tolerant of rapidly changing salinities since it is absent from major river estuaries. *Macoma balthica* tended to be smaller in the warmer waters of southern James Bay than in Hudson Bay, perhaps due to the lower salinity and the particle size of the substratum (Martini and Morrison 1987). However, parasitism may also play a role. Near Churchilll, Lim and Green (1991) observed that the more mobile individuals, and those living higher in the intertidal zone, were more heavily parasitized and grew faster than those that were more sedentary or living lower in the intertidal zone. They suggested that parasitic castration might account for their higher growth rate and mobility, and thereby increase the likelihood of the parasite completing its life cycle.

Molluscs common in the intertidal zone of Hudson Bay, which is generally depauperate, include the pelecypods *Hiatella arctica*, *Macoma balthica* and *Mytilus edulis*, the gastropods *Margarites costalis* and *Littorina saxitilis* and the chiton *Tonicella marmorea* (Macpherson 1971). Molluscs are more common and abundant offshore, where most of the species are typically Arctic. Their distribution in the bay as well as species composition is correlated more to substrate type than to water depth (Wagner 1969). Common and abundant molluscs that are widely distributed in the bay include the pelecypods *Nucula belloti*, *N. pernula*, *Portlandia lenticula*, *Musculus discors*, *Serripes groenlandicus*, *Macoma calcarea*, and *Chlamys islandica*. The pelecypod *Bathyarca glacialis* is abundant in the deep water of central Hudson Bay (Lubinsky 1980). Gastropods that have been reported from central Hudson Bay include *Lepeta caeca*, *Colus pubescens*, *Oenopota arctica* and *O. pyramidalis*, which are not very abundant (Wagner 1969; Macpherson 1971). *Lepeta caeca* and *M. costalis* are common and abundant nearshore along both east and west coasts of Hudson Bay; *Boreotrophon fabricii* is also common along the west coast while 6 other species are common along the east coast.

Some pelecypods in the James Bay marine region exhibit dwarfism relative to those in the Hudson Bay marine region (e.g., *Mytilus edulis*, *Astarte c. crenata*) (Lubinsky 1980). This may be related to differences in salinity and water temperature. In late autumn, many small *M. edulis* attach to the bases of eelgrass leaves in eastern James Bay (Lalumière et al. 1994). Iceland scallops (*C. islandica*) in eastern Hudson Bay also tend to be slow growing and small relative to other areas (Lambert and Prefontaine 1995).

The region appears to be a refugium for a number of typically Subarctic or boreal Atlantic pelecypods (e.g., *Mya pseudoarenaria*) whose distributions may be disjunct with those of their relatives elsewhere. Some species are rare in the Canadian Arctic (e.g., *Thracia devexa*, *T. septentrionalis*) and others are considered by

Lubinsky (1980) to be relict High Arctic populations that survive but may be close to extinction in James Bay and southeastern Hudson Bay (e.g., *Cuspidaria subtorta*, *Yoldiella intermedia*). The gastropod *Hydrobia minuta* occurs north to Akimiski Island along the west coast of James Bay, occupying the upper tidal flats up to and including the lower salt marshes (Figure 7-8). It flourishes in the warmer brackish to almost fresh water flats and may be a relict species.

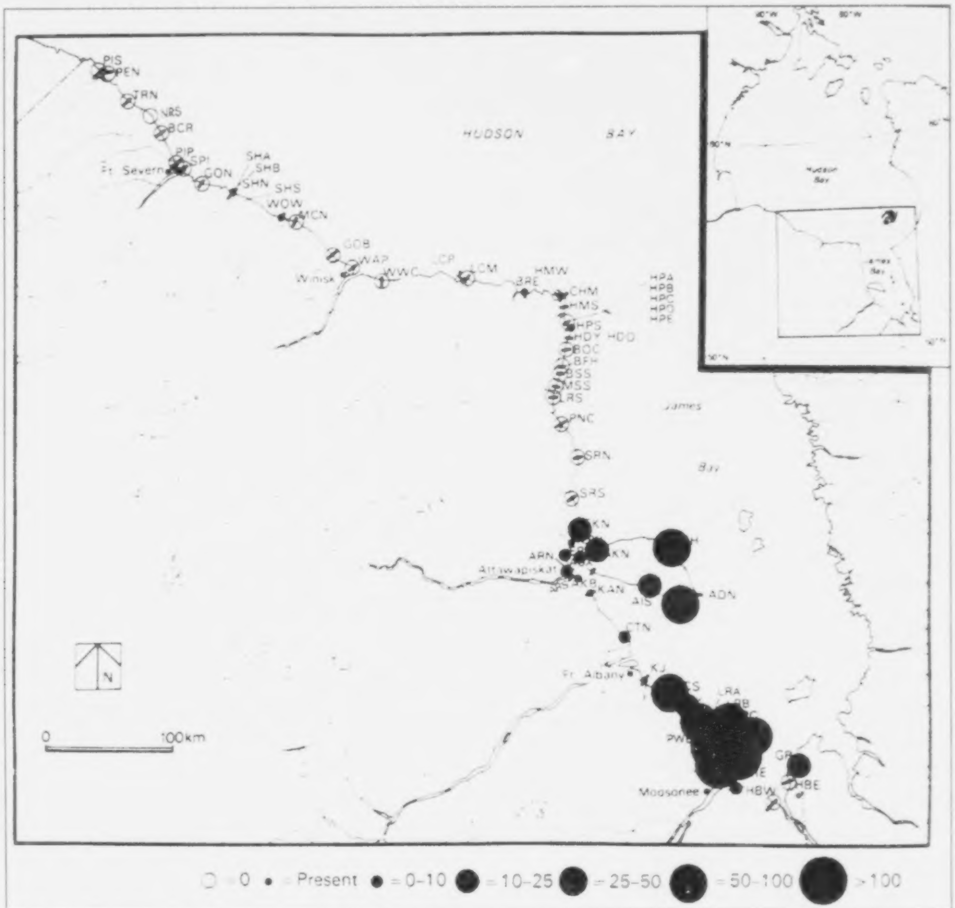

Figure 7-8. **Distribution of *Hydrobia minuta* along the Ontario coast expressed as a mean number of individual per transect (individuals/no. of samples treated for macrobenthos) (from Martini and Morrison 1987, p. 53).**

Molluscs are important prey for many fish, bird, and mammal species--including polar bear in James Bay that eat *Mytilus edulis* (Russell 1975). Pelecypods such as *Mya truncata*, *Serripes groenlandicus*, and *Clinocardium ciliatum* are important foods for walruses and bearded seals in Hudson Bay (Mansfield 1958; Smith 1981). Squid found in the stomachs of belugas and walrus from Hudson Bay were not identified (Doan and Douglas 1953; Mansfield 1958), but seabirds in northeastern Hudson Bay prey on *Gonatus fabricii* (Gaston et al. 1985). Seabirds in northeastern Hudson Bay also eat two species of pelagic gastropods, the pteropods or sea butterflies *Limacina helicina* (synonym *Spiratella helicina*) and *Clione limacina* (Gaston et al. 1985), both of which are common and widely distributed in James Bay and Hudson Bay (Willey 1931; Kerswill 1940). Inuit, particularly in the Belcher Islands, harvest the blue mussel (*M. edulis*) for food, and exploratory commercial fisheries have been conducted in eastern Hudson Bay for Iceland scallops (*C. islandica*) (see Section 14.3).

7.2.7 Phylum Echinodermata

Echinoderms are benthic invertebrates, represented in the Hudson Bay marine ecosystem by 5 classes comprising 39 species (Clark 1920, 1922, 1937; Grainger 1955, 1966). Of these, 35 occur in the Hudson Bay marine region and 25 in James Bay and southeastern Hudson Bay—most of which were reported from Richmond Gulf (Clark 1920, 1922; Grainger 1966). The echinoderms are distributed throughout Hudson Bay and James Bay and are not as restricted in distribution by substrate type as the molluscs. They are generally Arctic species and their regional abundance is not well known. Echinoderms are found on substrates ranging from mud to coarse gravel and rocks, some at depths less than 10 m but most at greater depths. Six species, the green sea urchin *Strongylocentrotus droebachiensis*; the sea cucumbers *Cucumaria japonica* and *Psolus fabricii*; and the sea stars *Urasterias lincki*, *Leptasterias groenlandica*, and *L. polaris* commonly inhabit the lower intertidal zone, and most also inhabit the deeper waters of Hudson Bay and James Bay (Clark 1920, 1922; Grainger 1965). The green sea urchin is perhaps the most common and abundant echinoderm in the James Bay and southeastern Hudson Bay (Clark 1922; Jamieson 1986; Giroux 1989; Morin 1991), while brittle stars may be the most common and abundant echinoderm in the rest of Hudson Bay (Barber et al. 1981). Polar bears on the Twin Islands eat these urchins in summer (Russell 1975), and Inuit from the Belcher Islands harvest the green sea urchin and six-rayed starfish for food (see Section 14.3).

7.2.8 Phylum Chordata: Sub-Phylum Urochordata

Urochordates or tunicates possess distinct chordate features as larvae and are invertebrates as adults (Barnes 1974). At least 22 species of ascidaceans (sea squirts), which are sessile filter-feeders as adults, and 3 species of larvaceans occur in the Hudson Bay marine ecosystem (Table 7-1; Appendix 2). All of the 15 species of ascidaceans and 3 larvaceans that occur in the James Bay marine region are Arctic forms, most with a circumpolar distribution (Huntsman 1922; Trason 1964; Barber et al. 1981).

Most of the ascidaceans inhabit the littoral zone, attaching by means of a filament or stalk mainly to rocky substrates, but also to clay/mud buttoms. *Boltenia echinata* and *B. ovifera* are common in southeastern Hudson Bay (Huntsman 1922; Trason 1964). *Rhizomolgula globularis* has been found in the stomachs of four-horn sculpin *Myoxocephalus quadricornis* in southeastern Hudson Bay (Huntsman 1922). The tiny, transparent larvaceans are neotenic as adults and specialized for a planktonic existence (Barnes 1974).

7.3 Summary

The invertebrate and urochordate fauna of the Hudson Bay marine ecosystem is poorly known. Little is known of the species composition of the water column, seafloor, or sea ice; or how species distribution, abundance, or biological productivity changes with the seasons or years—particularly offshore. Most of the detailed research has been conducted at estuaries downstream of existing or proposed hydroelectric developments in Quebec and Manitoba, either in open water during the summer or under the sea ice in the spring.

None of the 689 invertebrate and 25 urochordate species reported is unique to the Hudson Bay marine ecosystem, but 243 of them have not been reported from the Hudson Strait or Foxe Basin marine regions to the north. Of the latter, 94 species have only been reported from the James Bay marine region, which includes southeastern Hudson Bay. Some of these faunal differences will be artifacts of sampling. But, a number of species for which there is good sampling coverage appear to be relicts that survive in the warmer, less saline waters of James Bay but not in other Arctic marine regions. Most of the remaining invertebrate species are widely distributed outside this region, generally in Arctic waters. Estuarine species are distributed throughout James Bay and southeast Hudson Bay but are present in the highest density in or near river mouths, while freshwater forms do not survive far from the rivers. The Arctic marine species become dominant moving away from the large estuaries.

Few benthic species inhabit the intertidal zone on a permanent basis, likely due to ice scour, which can extend to a depth of 5 m, and to freezing. While most of the benthic invertebrates live below the ice scour zone, central Hudson Bay has a meagre benthic fauna that consists mostly of echinoderms, especially brittle stars, polychaetes, sea anemones and decapods. In estuaries, such as that of the Eastmain River, the marine zone has the most diverse benthic fauna, while the density of the benthic fauna in the brackish zone is very low compared with freshwater or marine areas.

The pelagic zone is characterized by comb jellies, arrow worms, copepods and amphipods, euphausids, and the pelagic sea butterflies. Species assemblages of marine zooplankton in James Bay and southeastern Hudson Bay reflect the massive freshwater inputs and estuarine character of the circulation. They are characterized by the presence of two euryhaline copepod species, *Acartia longiremis* and *Centropages hamatus*. Species assemblages to the north and offshore are characterized by typically Arctic species, related to the cyclonic circulation of Arctic water in central Hudson Bay. In James Bay, the varying ratios of zooplanktonic species characteristic of fresh, brackish, and marine water reflect seasonal pulsations in the surface brackish water and saline bottom water within the bay. The substantial bowhead population that once summered in northeastern Hudson Bay suggests that dense concentrations of Copepoda may be present in that area.

The ice fauna is not as well known as the ice flora. In April 1983, offshore the mouth of Grande rivière de la Baleine, it consisted largely of planktonic nematodes, rotifers, ciliates, and copepods--in order of abundance. The sea ice fauna was generally denser but less diverse than the zooplankton under the ice, both within and outside the river plume. The abundance was positively related to salinity, and to the presence of sea-ice microflora. Zooplankters beneath the ice are much more abundant below the brackish river plume than within it. They are important foods for larval fishes. Because the standing stock of sea-ice fauna and zooplankton is greater under marine conditions, it could be decimated by a winter expansion of the freshwater plume. This could have important effects on the marine food chain in the affected area.

Few species are of direct value to man, but many are indirectly valuable as food for fish, birds, and mammals. Belcher Islanders harvest and eat marine invertebrates to a greater extent than most other Inuit in Arctic Canada (see Section 14.3).

8.0 FISHES

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The apparent absence of a commercially exploitable offshore fishery resource has limited research on the fishes in Hudson Bay and James Bay. Few studies have been conducted offshore or in winter, few have been repeated in subsequent years, and sampling techniques have varied in their selectivity and efficiency. Because many marine fish species have only been caught at a few locations, little is known of population structure and dynamics or of ecosystem interrelationships. Research has focussed primarily on estuarine habitats that have been, or may be, affected by hydroelectric developments, and on anadromous salmonids that are harvested for food. Concern about the impact of altering the under-ice plume from rivers affected by hydroelectric development has spurred detailed research on the ecology of fish larvae offshore the mouth of the Grande rivière de la Baleine. There are important subsistence and commercial fisheries for anadromous Arctic charr along both the Nunavut and Nunavik coasts (see Section 14.4).

Traditional knowledge of the marine fishes is also limited. It consists largely of observations from shallow nearshore waters and from examinations of the stomach contents of harvested biota (Fleming and Newton 2003). Some of these observations are difficult to interpret, as hunters often do not differentiate between similar species of whitefishes, ciscos, cods or sculpins, or between capelin and sand lance. The "good, large size" cod reported near Lake Harbour by Fleming and Newton (2003:4), for example, are likely Greenland cod from Soper Lake and not Arctic cod (see Stewart and Bernier 1988). And, the Inuktitut name for capelin meaning "the ones that hide in the sand" (Fleming and Newton 2003:8)—likely refers to sand lance, which burrow into the sand, rather than capelin. Similar interpretation problems exist in the region's scientific literature.

This Chapter summarizes knowledge of fishes that use waters of the Hudson Bay marine ecosystem. Rather than present detailed discussions of the species based on literature from other regions, it concentrates on information from studies within Hudson Bay and James Bay.

8.1 ZOOGEOGRAPHY

At least 61 species of fish use waters of the Hudson Bay marine ecosystem, which includes the James Bay and Hudson Bay marine regions (Figure 1-1). Their scientific names are provided in Appendix 3, which includes a brief summary of each species' depth, salinity, and substrate preferences, movements and utilization. None of these fishes is unique to this ecosystem but the estuarine fish communities are unusual. Two other species, Greenland halibut and shorthead redhorse, may also be present. The former may have been collected from Richmond Gulf (Hunter et al. 1984); the latter will enter brackish water on rare occasions and is present in river systems along the coast of James Bay and southern Hudson Bay (Scott and Crossman 1973), suggesting that it may enter the estuaries. In 1955-56, eggs and fingerlings of the chum salmon (*Oncorhynchus keta*) and pink salmon (*O. gorbuscha*) were introduced to three rivers of the Hudson-James Bay basin (Hunter 1968). The object was to supplement the basin's anadromous fish resources. There was no known survival of fish from these experiments. Data from the Hudson Strait marine region, immediately to the north, are provided for comparative purposes. Too few data are available from the Foxe Basin marine region for useful comparison.

Despite the limited sampling, a few generalizations with regard to the ecosystem's fish fauna are possible: 1) the number of Arctic marine fish species increases moving northward from the relatively warm, shallow, dilute waters of southern James Bay; 2) the ability of freshwater species to withstand salt water is an important ecological adaptation for this region; and, 3) the relatively shallow depths may exclude many of the deepwater fishes that occur in Hudson Strait (Morin et al. 1980; Morin and Dodson 1986).

Of the species reported from Hudson Bay and/or James Bay: 25 stay in the marine environment throughout their lives; 10 are marine but use the estuaries seasonally or as nursery grounds; 9 spawn and overwinter in fresh water but enter the brackish coastal waters for varying periods during the summer to feed (anadromous); 16 are freshwater species with varying salt tolerances that occasionally enter the weakly brackish estuaries or coastal waters (semi-anadromous); one, the fourhorn sculpin, lives in the brackish estuaries year-round (estuarine); and another, the Atlantic salmon, spawns in freshwater but can winter in salt water (diadromous). The number of species reported is low relative to Hudson Strait (Table 8-1), and to other marine regions along the Atlantic coast of Canada (Scott and Scott 1988). The extent to which this reflects differences in sampling efforts is unknown.

Table 8-1. Habitat use by fish species reported from the James Bay, Hudson Bay, and Hudson Strait marine regions (see also Appendix 3).

Species' habitat use	Marine Region		
	James Bay*	Hudson Bay	Hudson Strait
marine (M)	22	22	64
typically marine but make seasonal use of brackish water (B)	10	9	10
estuarine (E)	1	1	1
anadromous (A)	7	8	7
diadromous (D)	1	1	1
typically freshwater but occasionally enter brackish water (S)	12	8	6
TOTAL	53	49	89

*Note: James Bay Marine Region includes southeastern Hudson Bay, see Figure 1-1.

Anadromous and semi-anadromous fishes are less common in the more saline coastal waters of western and northern Hudson Bay than in the relatively dilute waters of James Bay and southern Hudson Bay (Table 8-1). Lake trout, lake cisco, lake whitefish, round whitefish, and burbot, which are common anadromous fishes in the estuaries and coastal waters of James Bay and southeastern Hudson Bay (Morin et al. 1980; Fleming and Newton 2003), are not common in the brackish coastal waters of western Hudson Bay (D. McGowan and G. Carder, DFO, Winnipeg, pers. comm. 1991). One anadromous species that is more common in the coastal waters of western and northern Hudson Bay is the Arctic charr. Hudson Bay and James Bay are both relatively shallow and lack the deepwater species that inhabit Hudson Strait.

Two recent developments in the zoogeography are of particular ecological interest, apparent changes in the species composition in northern Hudson Bay and the introduction of rainbow smelt.

Fisheries survey data are insufficient to identify changes in species composition but proxy data are available from Canadian Wildlife Service studies of seabird diets. The species composition of marine fishes in the diet of thick-billed murre (*Uria lomvia*) nestlings in northern Hudson Bay shifted over the period 1980 to 2002 (Gaston et al. 2003). The occurrence of Arctic cod, sculpins, and benthic Zoarcidae decreased while that of capelin and sand lance increased Figure 8-1). Arctic cod fell from a mean of 43% of deliveries in the mid-1980s to 15% in the late 1990s; sculpins and zoarcids fell from 36% to 15%. Deliveries of capelin increased from 15% to 50% over the same period. These changes were associated with a halving of the July ice cover in Evans Strait over the period 1981-99, and may reflect the effects of a general warming of Hudson Bay waters on the relative abundance of these fish species (Gaston et al. 2003).

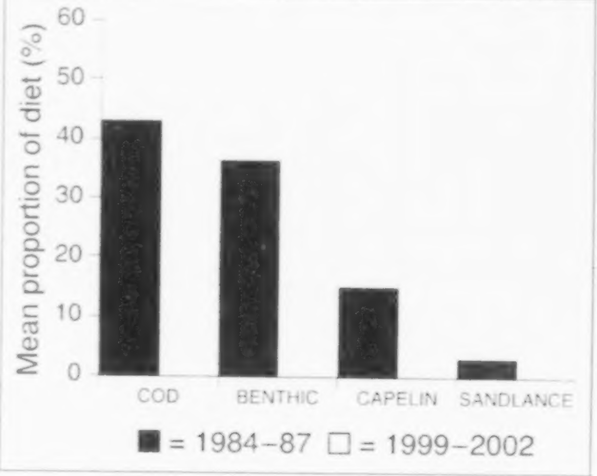

Figure 8-1. **Proportion of fish prey types delivered to thick-billed murre chicks in 1984-87 and 1999-2002 (benthic = sculpins + zoarcids)(from Gaston et al. 2003, p.231). Values are means of annual proportions. Differences between periods for each prey type were significant at p<0.01.**

Rainbow smelts (*Osmerus mordax*), presumably from the Atlantic population, have been illegally introduced into the Hudson Bay drainage at lakes in the Rainy and English/Wabigoon river systems of northwest Ontario (Campbell et al. 1991; Franzin et al. 1994; Stewart et al. 2001). They were first reported from the south basin of Lake Winnipeg in 1991 and by 1998 had spread down the Nelson River to the estuary (Figure 8-2; Remnant et al. 1997; Zrum 1999). In 2002 they were taken 15 km upstream from the mouth of the Churchill River, having ventured along the Hudson Bay coast against the prevailing currents (D. Remnant, North/South Cons. Inc., Winnipeg, pers. comm. 2003). There is evidence for spawning of the species in the lower Nelson River basin (Zrum 1999).

The spread of this small, predatory anadromous fish is a concern for commercial fisheries (Franzin et al. 1994; Stewart and Watkinson 2004). Rainbow smelts are voracious predators of invertebrates. They compete directly for food with various commercially harvested species, particularly whitefishes and ciscos, and prey upon their eggs and larvae. Rainbow smelts are in turn eaten by other harvested fish species such as walleye and lake trout. Walleye that have rainbow smelts in their stomachs when they are captured in gillnets deteriorate very quickly (D. Remnant, North/South Cons. Inc., Winnipeg, pers. comm. 2003). If they are not cleaned immediately on capture their flesh is unmarketable within hours.

The potential impact of the spread of this species along the coasts of Hudson and James bays and into other river systems has not been examined. Elsewhere, its introduction has reduced the populations of pelagic and benthic planktivores and increased the growth and fat content of game and commercial fish that begin eating it Stewart and Watkinson 2004). This increases mercury content of the latter and reduces their quality for human consumption. However, the rainbow smelt is also an excellent food fish in its own right and supports both commercial and recreational fisheries in the Great Lakes and Atlantic Canada. The potential effects of this introduced species on commercially harvested salmonid species in the Hudson Bay ecosystem merits close and immediate examination.

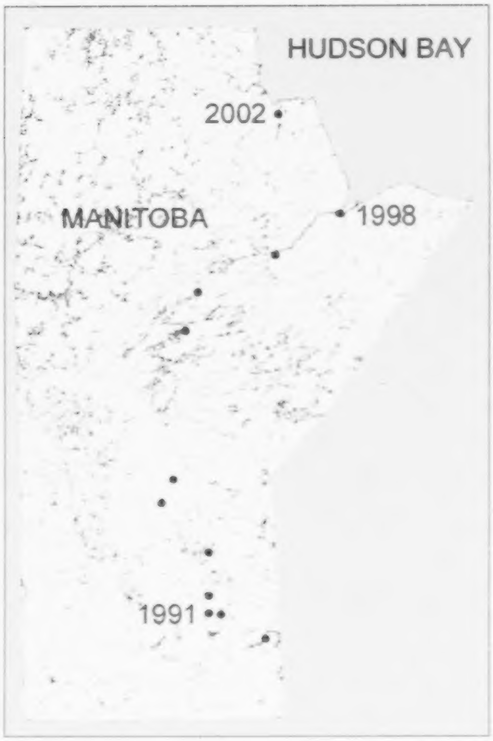

Figure 8-2. **Spread of rainbow smelt in the Hudson Bay drainage (adapted from Stewart and Watkinson 2004).**

8.2 MARINE FISHES

The paucity of marine fisheries research in the region limits what can be said of its' marine fishes. Indeed, the offshore fisheries resources are virtually unknown. Some aspects of the ecology of capelin, Arctic cod, Greenland cod, and sand lance have been studied, and will be discussed further.

8.2.1 Capelin

The capelin is an important food for Arctic cod, anadromous Arctic charr, seals, beluga whales, and fish-eating birds (Fleming and Newton 2003). It has a circumpolar distribution that extends along the mainland coast of Canada and into the southernmost Arctic islands (McAllister 1963b; Hunter et al. 1984). The species is common in summer at estuaries along the Quebec coast (Morin and Dodson 1986; Fleming and Newton 2003) and west to at least the Nelson and Churchill estuaries (Watts and Draper 1986; Baker 1989).

Large numbers of capelin spawn on shingle beaches in the Belchers in July-September (Dunbar 1988; Fleming and Newton 2003) and on beaches in the vicinity of Port Nelson, near the mouth of the Nelson River estuary, in June (Comeau 1915). Larvae with yolk sacs (4-6 mm) are abundant and widespread in the Nelson River estuary in July, suggesting that they hatch in late June or early July (Baker 1996; Horne 1997; Horne and Bretecher 1998; Zrum 1999, 2000). They are most common in the Nelson River estuary at high tide, when densities of >100 individuals$\cdot$m^{-3} are not uncommon, particularly in deeper water. In July, larvae with yolk sacs are also present in concentrations of up to 3.2 individuals$\cdot$m^{-3} in the Churchill River estuary and offshore, suggesting that capelin spawn in and near the estuary in June or early July (Lawrence and Baker 1995). Little is known of the ecology of adult capelin in the region. However, dietary studies of thick-billed murre suggest that they have become more abundant in northern Hudson Bay over the past two decades (Gaston et al. 2003).

8.2.2 Arctic Cod

Arctic cod are a vital link in the food chain of the Hudson Bay marine ecosystem, where they can occur in vast schools (Morrison and Gaston 1986; Fleming and Newton 2003). These small pelagic cod have a circumpolar Arctic distribution and are distributed widely in Hudson Bay (Hunter et al. 1984; Scott and Scott 1988). Many fishes, seals, whales, and marine birds eat them. Arctic cod in turn eat a variety of smaller fishes, crustaceans, and polychaetes. Their ecology has been studied in detail in the High Arctic (e.g., Bradstreet et al.

1986) but is poorly known in Hudson Bay. In the High Arctic, juvenile and adult fish are found either dispersed throughout the water column or in large, dense schools. They are smaller and shorter-lived than Greenland cod, seldom attaining a length of more than 300 mm or an age of 7 years. They are often associated with ice cracks or edges and move inshore in late summer. Larval Arctic cod are very common in the coastal waters of southeastern Hudson Bay (Ponton and Fortier 1992; Ponton et al. 1993; Fortier et al. 1995, 1996). Their ecology is discussed in the section that follows on estuarine communities.

Little is known of the ecology of adult Arctic cod in the region. However, dietary studies of thick-billed murre suggest that they have become less abundant in northern Hudson Bay over the past two decades (Gaston et al. 2003). Inuit from Repulse Bay and Akulivik also report that they are less abundant than in the past (Fleming and Newton 2003).

8.2.3 Greenland Cod

Greenland cod are demersal, non-schooling fish (Mikhail and Welch 1989). This Arctic and cold temperate species is distributed in coastal inlets and estuaries along the east coast of Hudson Bay south to at least the Eastmain River estuary in James Bay and along the west coast of Hudson Bay south to Arviat (Ochman and Dodson 1982; Hunter et al. 1984). Studies at Saqvaqjuac Inlet in northwestern Hudson Bay (63°N) did not capture them on the open coast (Mikhail and Welch 1989). This, coupled with the lack of species reports, suggests that the species may avoid the relatively shallow and exposed coasts of southwestern Hudson Bay and western James Bay. There is no evidence that they undertake large-scale migrations. In James Bay individuals seem to move offshore in the summer as the temperature of coastal waters increases and inshore into estuaries in winter (Morin et al. 1991). They may be more sedentary at Saqvaqjuac, where gradients in temperature and food concentrations are smaller.

These cod can tolerate salinities as low as 4 ppt (≈psu) (Ochman and Dodson 1982) and temperatures up to 20°C (Morin et al. 1991). In eastern James Bay, they occupy shallow (2-5 m) coastal waters that have a belt of eelgrass at 1-3 m depth in summer. At Saqvaqjuac, they are evenly distributed near the bottom to 35 m depth (Mikhail and Welch 1989). Spawning occurs between April and June in James Bay and in March and early April at Saqvaqjuac, possibly in estuaries. Little is known about the early life stages of the species. Individuals can grow to 700 mm in length and live 12 years (Mikhail 1985; Morin and Dodson 1986; Mikhail and Welch 1989; Morin et al. 1991). They mature at 2-4 years, spawn annually thereafter, and have a high fecundity. Greenland cod eat a variety of fishes and benthic crustaceans. They grow larger than Arctic cod and may be less common prey for marine mammals and birds.

8.2.4 American Sand Lance

These small fishes are common in the inshore waters of Hudson Bay. They typically occur over sandy bottom in large schools and, when not schooling, will burrow into sandy bottom where they may remain above the low tide level between tides (Scott and Scott 1988). They are one of the most abundant species in the Nelson River estuary in summer, occurring at densities of up to 10 individuals$\cdot$m^{-3} at high tide, and are most common in the stratified offshore estuarine zones (Baker 1989, 1996; Horne and Bretecher 1998; Zrum 1999, 2000). Their distribution within the estuary is patchy but they are captured consistently in shallow water (3-6 m) of intermediate salinity (15-20 ppt [≈psu]). Adults, juveniles, and larvae, some with an egg sac, frequent the estuary. The larvae are planktonic until they grow to about 30 mm in length, and primarily benthic thereafter. Sand lance larvae are also common in the coastal waters of southeastern Hudson Bay (Ponton and Fortier 1992; Ponton et al. 1993; Fortier et al. 1995, 1996). Their ecology is discussed further in the following section.

8.3 ESTUARINE FISH COMMUNITIES

The relative importance of the freshwater species that exploit the extensive brackish zone is characteristic of the fish fauna of James Bay and southern Hudson Bay (Morin and Dodson 1986; Schneider-Vieira et al. 1993). Lake trout, lake cisco, lake whitefish, round whitefish and burbot, which commonly inhabit fresh water, frequent the mainland estuaries from the Nelson River south and east to the Innuksuak River to the extent that they are considered to be anadromous. These species make similar use of the Mackenzie River estuary (Stewart et al. 1993b) and/or the Chantrey Inlet-Rasmussen Basin area (Stewart and Bernier 1983) but are not common in brackish coastal waters elsewhere in Hudson Bay. The estuaries of southern James Bay also support a number of other freshwater species that are seldom reported from brackish water, including white sucker, walleye, slimy sculpin, spoonhead sculpin, and brook stickleback.

The Salmonidae, Catastomidae, and Cottidae dominate fish communities in the estuaries of Rupert's Bay and of the Eastmain, Maquatua, La Grande, Grande Baleine, Petite Baleine, Innuksuac, Nelson, and Churchill rivers (Morin et al. 1980, 1992; Morin and Dodson 1986; Kemp et al. 1989; SEBJ 1990; Schneider-Vieira et al. 1993). The species composition of these fish communities changes with latitude. Arctic and Subarctic species such as Arctic charr, Greenland cod, and shorthorn sculpin are rare or absent in the estuaries of southern James Bay, while there are fewer freshwater species in the northern estuaries (Morin et al. 1980; Schneider-Vieira et al. 1993). These differences are likely related to a variety of physical and biological factors, such as post-glacial dispersion, competition, habitat availability, climate, and/or oceanography. Resistance to freezing in sub-zero coastal waters is one important determinant of the fishes' seasonal movements. Marine species such as Greenland cod and shorthorn sculpin are freeze-resistant, so their winter movements are unlikely to be restricted by low temperature (Whoriskey et al. 1994). Anadromous species such as lake cisco and brook trout are less resistant to sub-zero temperatures and shift their winter distributions into areas where their blood plasma will not freeze—typically closer to river mouths or into fresh water.

Seasonal movements of fishes that frequent the estuaries can be complex and are influenced by variations in temperature and salinity and by species' biological requirements (Lambert and Dodson 1982a; Kemp et al. 1989). Indeed, estuaries may serve as refugia from the winter stresses of both marine and riverine (lotic) environments (Roy 1989). The life cycles of anadromous lake cisco and lake whitefish are perhaps best known and serve to illustrate these complexities (Figure 8-3). Differences in the energetic costs of these migrations may play an important role in determining the reproductive strategy followed by each species (Dodson et al. 1985; Lambert and Dodson 1990a+b). Both of these anadromous salmonids exhibit reduced fecundity moving northward, largely due to later maturity and less frequent spawning (Morin et al. 1982). The life cycles of other fish that use James Bay and southern Hudson Bay are likely equally complex (see also Dutil and Power 1980).

Brackish waters of the Nelson River estuary provide important summer feeding and nursery habitat for juvenile lake cisco, lake whitefish, and longnose sucker from the lower Nelson River (Baker 1989, 1990). While a range of other typically freshwater species use the estuary in summer, few adults of these species have been caught there. Adult lake cisco are seldom caught in the Nelson River mainstem in summer (Remnant and Baker 1993) but are taken in the fall when they move into its' tributaries to spawn (MacDonell et al. 1992; MacDonell 1993). Their apparent rarity in the Nelson River and its estuary suggests that many adults move along the coast of Hudson Bay in summer. These summer sojourns can be extensive, as tagged fish do move between the Churchill and Nelson rivers (Lawrence and Baker 1994). They appear to winter near the mouth of the Nelson River or within the estuary (MacDonell et al. 1992). In contrast, adult lake whitefish may forage occasionally in the estuary but appear to conduct most of their activities in the Nelson or its' tributaries (Baker 1990; MacDonell and Bernhardt 1992). Whitefish (which likely includes the lake cisco), capelin and suckers have been found in the stomachs of beluga whales taken from the Nelson River area (Comeau 1915).

In contrast to the Nelson River estuary, the abundance of fish in the Churchill River estuary in summer is low (Baker et al. 1994). This may be related to the very low density of zooplankton. Sampling at the surface and

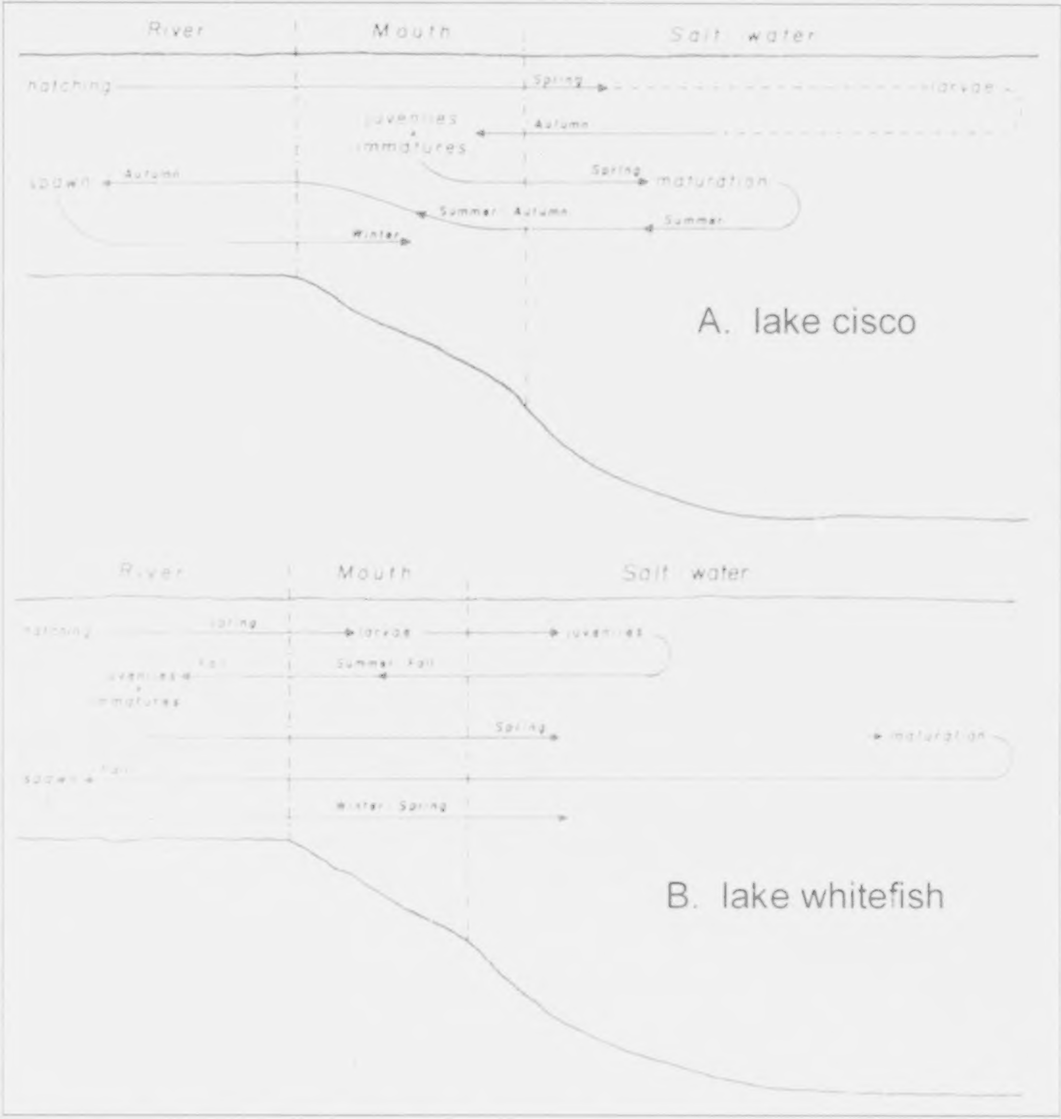

Figure 8-3. The life cycles of anadromous (A) lake cisco (*Coregonus artedi*) and (B) lake whitefish (*C. clupeaformis*) in coastal James Bay (adapted from Morin et al. 1981, p. 1605). Horizontal lines indicate movements of the fishes through the freshwater, river mouth, and saltwater zones from hatching to postspawning. Arrows indicate the direction of movement and collection locations; dashed lines indicate speculative movements. The vertical arrangement of the lines is not related to the depth distribution of the fish.

in deep water using Isaacs-Kidd trawls during August 1993, yielded few large invertebrates and no adult fishes. Most fish, primarily young-of-the-year capelin and sand lance, were captured in zooplankton nets.

Stocks of lake cisco in the rivers of eastern Hudson Bay may be reproductively isolated, perhaps by salinity or temperature barriers, whereas those to the south in eastern James Bay appear to constitute a single reproductive unit (Bernatchez and Dodson 1990). This is supported by the apparent absence of larval retention and demonstration of straying among rivers in James Bay. Similar straying occurs between the Nelson and

Churchill rivers in southwest Hudson Bay (Lawrence and Baker 1994). It has important implications for stock management.

The estuaries also provide important nursery habitat for larval fishes. The larval communities of the Eastmain (Ochman and Dodson 1982) and Grande Baleine (Drolet et al. 1991; Gilbert et al. 1992; Ponton and Fortier 1992; Ponton et al. 1993; Fortier et al. 1995, 1996) estuaries are highly structured both spatially by salinity and temporally by date of hatch; many of the larval taxa emerge before ice breakup (Figure 8-4). This separation probably limits interspecific competition. The estuaries support larvae that hatch upstream in fresh water and are swept downstream by spring runoff, and those of marine and estuarine spawning species. The timing and extent of the freshet influences the distribution of the marine larvae and determines when larvae of anadromous and freshwater species enter the Bay (Ponton et al. 1993).

In the spring and summer of 1988-90, Arctic cod and sand lance were the most abundant larvae in and around the plume of Grande rivière de la Baleine (Ponton et al. 1993). The larval densities of Arctic cod, sand lance, slender eelblenny, and gelatinous snailfish were greatest in salinities >25 psu; Arctic shanny, sculpins, and capelin larvae were more abundant at salinities between 1 and 25 psu; and burbot and coregonine larvae were associated with fresh or brackish water even in Hudson Bay.

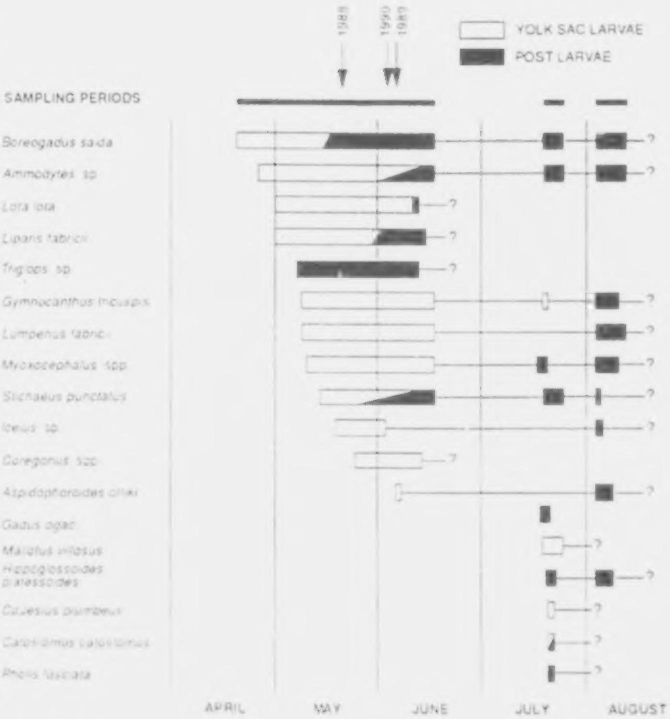

Figure 8-4. **Seasonal occurrence of the larval fish species caught during 1988-90 in Hudson Bay offshore Kuujjuarapik (from Ponton et al. 1993, p.325). Arrows indicate the start of ice breakup in the Bay offshore Kuujjuarapik. Ice breakup in Grande rivière de la Baleine generally occurred 10 days earlier.**

Larvae at the Grande Baleine estuary exhibit two survival strategies; sand lance and Arctic cod produce many, small larvae that hatch before ice breakup and feed on relatively small prey, while shannies (Stichaeidae) and sculpins (Cottidae) produce fewer, relatively large larvae that emerge after breakup and prey on larger items (Drolet et al. 1991). Before the spring freshet the sand lance and Arctic cod larvae are marginally more abundant offshore, where porous sea ice supports the development of ice algae, than inshore where freshwater inhibits algal growth (Gilbert et al. 1992).

Estuarine habitats provide important food resources for freshwater and anadromous species. Important foods for anadromous salmonids include: freshwater insect larvae that are carried downstream into the estuaries; small marine fishes such as capelin, eelblenny and sand lance; marine molluscs and amphipods (Hunter et al. 1976; Greendale and Hunter 1978; St.-Arsenault et al. 1982); and catostomids (Magnin and Clement 1979).

The estuaries also provide important food resources for marine species and for some, such as capelin (see above), important reproductive habitat. First-feeding larval Arctic cod and sand lance, for example, accumulate under the spring ice at the pycnocline below the brackish plume of Grande rivière de la Baleine (Figure 8-5; Ponton and Fortier 1992). This habitat offers them salinities they can tolerate and the optimal combination of prey density and visibility. If the plume becomes too thick (i.e., depth of 25 ppt [≈psu] isohaline >9 m) the larvae stop feeding (Fortier et al. 1996). Outside the plume area, where the surface meltwater layer is less turbid than the river plume, the under-ice distribution of larval Arctic cod and sand lance is less stratified and may be less constrained by light penetration and salinity. Their feeding success and growth also depends upon how well the timing of their hatch matches the reproductive cycle of the copepods they prey upon (Fortier et al. 1993). While the fish species hatch at about the same time each year, the copepod lifecycle is not always in synchrony so the nauplii they eat are not always available at the right time. Their dependence on the timing of the freshet and plume dynamics suggests a direct link between climate and survival of these species' larvae in the area affected by the plume (Fortier et al. 1996).

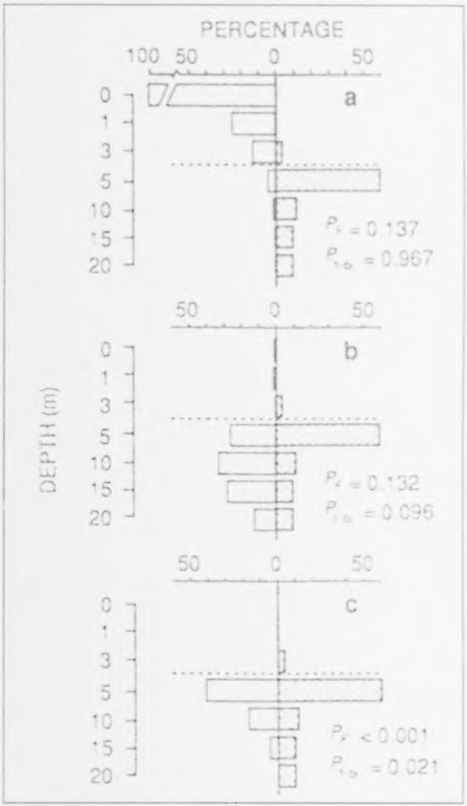

Figure 8-5. **Vertical distribution of Arctic cod (*Boreogadus saida*) larvae =7 mm (hatched histograms) offshore Grande rivière de la Baleine relative to (a) percent irradiance at depth, (b) percent food density at depth, and (c) percent food availability at depth (i.e., % food density x % irradiance) (from Ponton and Fortier 1992, p.223). Dotted line indicates pycnocline. Note the compressed vertical scale.**

8.3.1 Anadromous Arctic Charr

Arctic charr are discussed here at greater length than the other anadromous species because of their importance to the Inuit of Hudson Bay, who harvest them for subsistence and commercial sale (see also Section 14.4).

The Arctic charr has a circumpolar distribution that is the most northerly of any freshwater fish. Its populations can be anadromous or landlocked (McPhail 1961; McPhail and Lindsey 1970; Scott and Crossman 1973; Johnson 1980). The anadromous form is abundant in coastal areas of the Canadian Arctic but is not usually distributed far inland, except in the larger rivers. It is common in coastal areas of northern Quebec and Nunavut but less so in Ontario and Manitoba.

Anadromous charr migrate downstream during ice break-up from mid June to early July to spend the summer feeding in Hudson Bay and James Bay, and return upstream from mid August to mid September to overwinter in fresh water (Sprules 1952; Johnson 1980; McGowan 1987). They have been captured in salinities of up to 32 ppt (psu) in the Beaufort Sea (Craig 1984; Bond and Erickson 1987) but have not been reported from saline water in winter. This supports the belief that they leave the sea and overwinter in fresh waters to avoid sub-zero marine waters.

During the summer anadromous Arctic charr range widely along the Hudson Bay coast (Figure 8-6). Indeed, one charr tagged at Sandy Point, Nunavut was recaptured at Winisk, Ontario--a distance of over 800 km (G.W. Carder, DFO, Winnipeg, pers. comm.), while another tagged at Maguse River, Nunavut travelled northward at a rate of 33 km per day to the Ferguson River (MacDonell 1989). Migrants do not always return to their natal river systems to overwinter, but generally do so during spawning years (Johnson 1980; McBride 1980; Gyselman 1984).

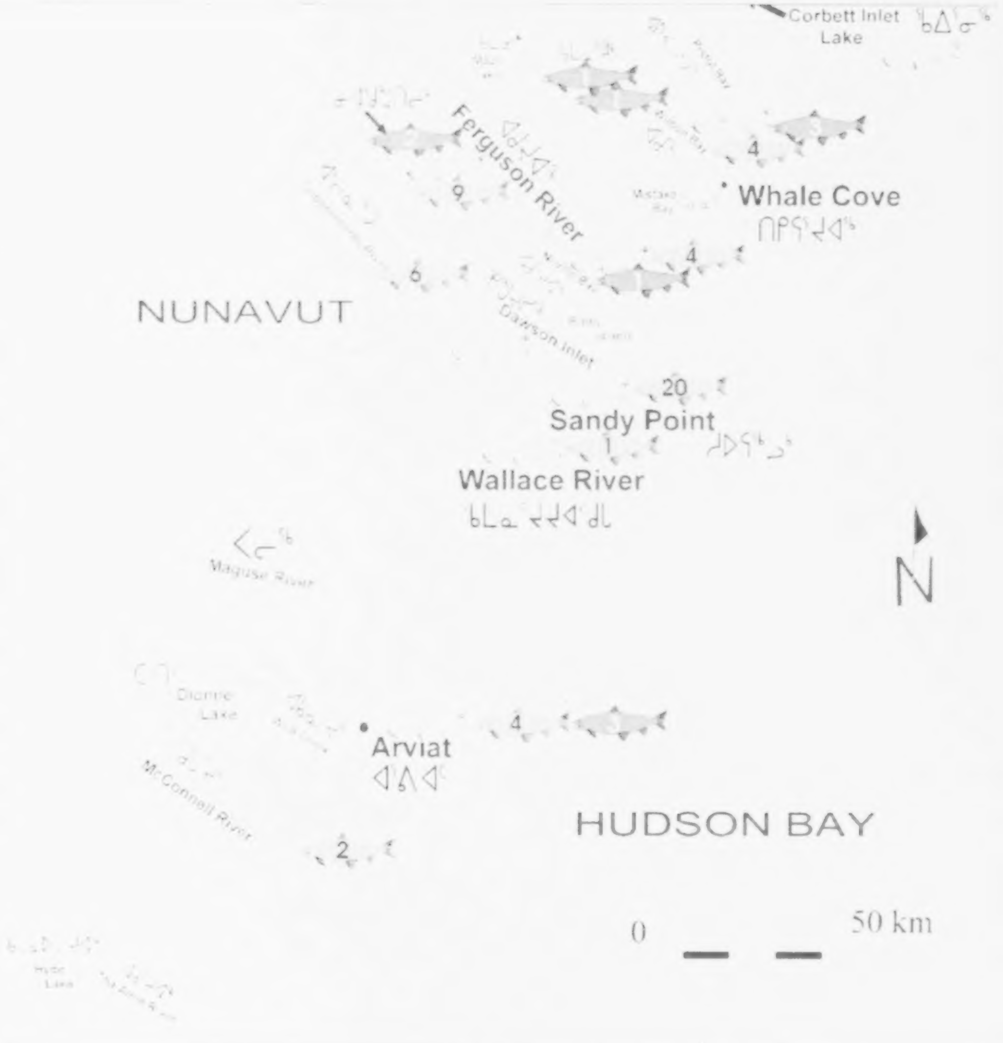

Figure 8-6. Movement of anadromous Arctic charr along the Kivaliq coast of Hudson Bay (adapted from McGowan 1998, p. 39). In June 1995, 493 Arctic charr were tagged during the downstream run at the Ferguson River. This map shows the number of charr recaptured by fishermen at different locations in 1995 (yellow), 1996 (red) and 1997 (blue).

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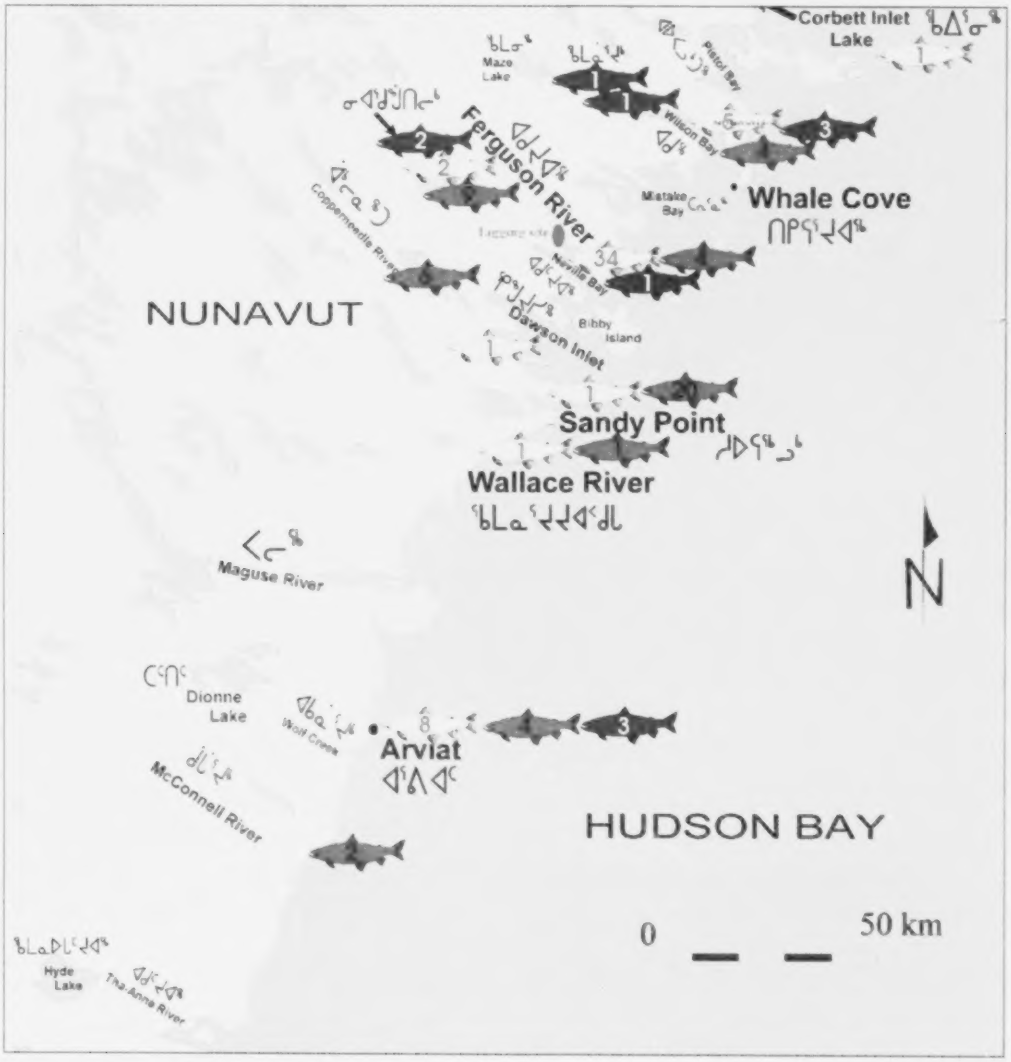

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Arctic charr in the Hudson Bay region spawn in fresh water during late August, September, and early October (Sprules 1952; Johnson 1980; Stewart and Bernier 1984; K. Martin-Bergmann, DFO, Winnipeg, pers. comm.), generally over gravel bottom in an area where current is sufficient to keep the eggs detritus-free and deep enough to protect them from freezing (Moore 1975; Johnson 1980). Eggs hatch in April or May and young pre-anadromous charr spend several years in fresh water, followed by 2 to 4 seasons of migrations to sea for feeding, before reaching sexual maturity. Maturity for both sexes is reached between ages 5 and 12 years and mature fish seldom spawn in consecutive years (Grainger 1953; Johnson 1980; Stewart and Bernier 1984).

Arctic charr in Hudson Bay eat predominately amphipods, mysids, and fish (Sprules 1952; Stewart and Bernier 1984). Because food is more abundant at sea they generally grow faster and larger than charr that remain in fresh water but are shorter-lived. Along the Kivalliq coast anadromous charr can grow to a fork length of 880 mm and live 23 y (Carder and Peet 1983).

Anadromous Arctic charr are attractive fish to subsistence, commercial, and sport fishers because they are available spring and fall in quantity at known locations. They grow faster and generally larger than landlocked charr, and are almost always in better condition--having higher coefficients of condition and fewer *Diphyllobothrium* spp. parasites encysted in the body cavity (Johnson 1980; Stewart and Bernier 1984).

8.4 SUMMARY

Knowledge of fishes in the Hudson Bay marine ecosystem is scant except for harvested anadromous species, and in the vicinity of estuaries that have been or may be affected by hydroelectric development. Lack of a proven, commercially viable offshore fisheries resource has limited offshore fisheries research, and ice conditions have limited seasonal research. Relatively little is known of fishes along the Ontario coast or offshore.

At least 61 species of fish use waters of the Hudson Bay marine ecosystem—fewer than are present in Hudson Strait and along the Atlantic coast. James Bay and southern Hudson Bay support characteristic and unusual estuarine fish communities that consist of a mixture of Arctic marine, estuarine, and freshwater species. These communities include more freshwater and anadromous species and fewer Arctic and deepwater species than those in western and northern Hudson Bay. The entire ecosystem is relatively shallow and lacks the deepwater species that inhabit Hudson Strait.

The composition of the estuarine fish communities changes with latitude. To the south the Arctic marine species are poorly represented, and to the north and offshore there are fewer freshwater species. Freshwater species make particular use of the estuaries along the Quebec coast, from the Eastmain River estuary northward to and including Richmond Gulf, where the waters are relatively warm, shallow, and dilute. The ability to exploit the extensive brackish zone is an important ecological adaptation for both the freshwater and Arctic marine species. Their seasonal movements are often complex and are influenced by variations in temperature and salinity, and in their biological requirements. The estuaries provide important seasonal foraging and nursery habitat for many species, spawning habitat for some, and year-round habitat for fourhorn sculpin.

Two recent changes in the zoogeography are of particular ecological interest. First, species composition in northern Hudson Bay may have shifted over the past two decades, with a decrease in the relative abundance of Arctic cod and an increase in that of American sand lance—possibly related to warming. Second, recent introduction of rainbow smelt (*Osmerus mordax*) into coastal river systems of Hudson Bay has the potential to damage coastal fisheries. The species is actively invading systems along the Hudson Bay coast and, elsewhere, has been implicated in the decline of native lake whitefish and cisco populations. Both of these developments merit further study.

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9.0 MAMMALS

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Waters and/or ice habitats of the Hudson Bay marine ecosystem are used by at least five species of whales, by walruses, five species of hair seals, Arctic foxes, and polar bears. Among the whales, belugas, narwhals and bowheads are migratory Arctic species that frequent the region as ice conditions permit. Killer whales live at all latitudes and migrate into Hudson Bay in summer; the minke whale is a temperate-water species and rare summer visitor to the region. There are also reports of sperm whales and northern bottlenose whales in Hudson Bay but their occurence has not been confirmed and at best they are rare. Concentrations of belugas in the estuaries of the Nelson, Churchill, and Seal rivers in July and August are some of the largest known. Belugas are the only whales found commonly in James Bay and southeastern Hudson Bay. Walruses, ringed seals, bearded seals, and harbour seals are resident while harp and hooded seals are seasonal visitors to the region. Arctic foxes and polar bears frequent coastal areas in summer and ice habitats during other seasons.

Traditional subsistence harvests of marine mammals are important to the native cultures and economy of the region (see also Chapter 14). Commercial whaling, particularly for bowheads and belugas, was instrumental in the European exploration and development of the region and dates back to the late 1600's in northern Hudson Bay. Whales are no longer harvested commercially, but bowhead populations and the eastern Hudson Bay beluga stock have not recovered from past commercial harvests and remain depleted. European embargoes have nearly eliminated commercial sealing in the region (Stewart et al. 1986).

The vulnerability of marine mammals to contaminant loading and the effects of climate change, respectively, is discussed in Chapters 16 and 17. Because many marine mammals are upper level consumers, they are vulnerable to contaminant accumulation. The polar bear and other species that that rely on ice as a platform for feeding, moulting, movement, and/or breeding are vulnerable to climate driven changes in the ice environment of Hudson Bay and James Bay.

9.1 BELUGA *Delphinapterus leucas* (Pallas, 1776)

As its Latin name implies the beluga, or white whale, has no dorsal fin and is white in colour as an adult (Brodie 1989; Stewart and Stewart 1989). It has a circumpolar Arctic and Subarctic distribution, and occurs throughout Hudson Bay and James Bay, where it is the most common and abundant species of whale. Despite the fact that Europeans have harvested belugas from Hudson Bay since 1688 (Rich and Johnson 1957 in Reeves and Mitchell 1987), the species' seasonal movements and stock dynamics are not well understood. This makes it difficult to manage the ongoing subsistence harvests of these whales.

The persistent presence of belugas at specific estuaries, local population depletion, morphometrics, and the timing of movements all suggest that there are separate stocks of belugas summering in Ungava Bay, Foxe Basin, eastern Hudson Bay, and western Hudson Bay (Sergeant 1973, 1981; Finley et al. 1982). [Note: While these "stocks" have been delineated for the purpose of hunt management, they often represent the best current delineation of biological populations.] This is supported by the observation that belugas at the Nastapoka River estuary show site tenacity during the summer and between years (Caron and Smith 1990). It is also supported by studies of molecular genetics which suggest that hunters in eastern Hudson Bay, Sanikiluaq and Kimmirut take animals from different stocks; that belugas summering in the Churchill River estuary may constitute another separate stock (de March and Postma 2003); and that there are differences between belugas summering in eastern and western Hudson Bay (Helbig et al. 1989; Brennin et al. 1997). Genetic information is not yet available from other major summer concentrations near the estuaries of the Seal, Nelson, Winisk, and Severn rivers, or from James Bay (de March and Postma 2003).

The hypothesis of geographical separation has been complicated by observations that belugas are distributed more or less continuously along the coasts of Hudson and James bays (Smith and Hammill 1986; Richard et al. 1990), and may winter together in Hudson Strait (Finley et al. 1982). Indeed, hunters in northern Quebec, northern Hudson Bay, and Arviat apparently take animals from a mixture of different stocks (de March and Postma 2003). Recent tagging studies have confirmed the exchange of animals among summering areas along the southwest coast of Hudson Bay, northern and central James Bay, and the Belchers (Richard and Orr 2003) (Figure 9-1).

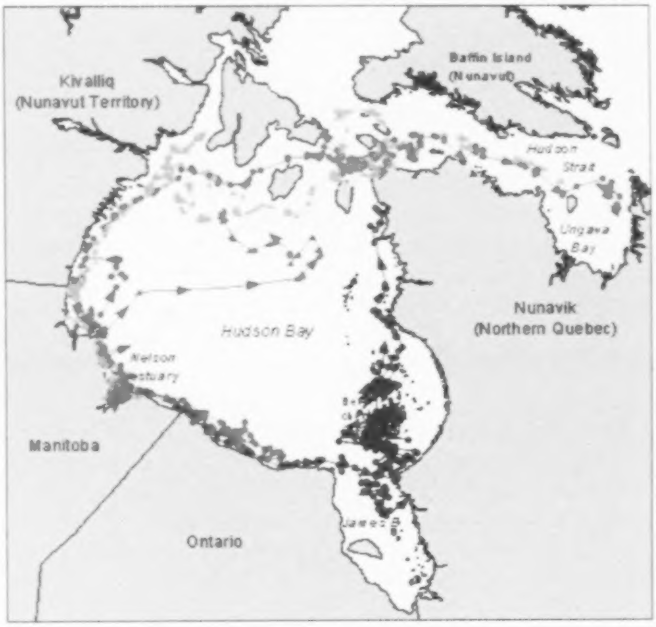

Figure 9-1. **Seasonal movements of 5 belugas radio-tagged at the Nelson River estuary between 30 July and 5 August 2003 and followed until 27 November 2003 (Richard and Orr 2003). Arrows show direction of movement. Purple (?) and dark green (?) tracks were made by female belugas—a calf accompanied the former.**

9.1.1 Distribution and Movements

The winter distribution and movements of belugas are limited by the presence of heavy pack ice or landfast ice where breathing holes cannot be maintained (Stewart and Stewart 1989). Of 5 animals tagged between 31July and 4 August 2003 at the Nelson River estuary, 3 travelled to eastern Hudson Strait and Ungava Bay by mid-November and the other two were travelling north in that general direction when the signals from their tags were lost in late October (red) and Late November (purple), respectively (Richard and Orr 2003). Aerial surveys of Hudson Strait, Ungava Bay, and northwest Hudson Bay in March have found belugas to be numerous in Hudson Strait and rare in Roes Welcome Sound and northern Hudson Bay (Finley et al. 1982; Richard et al. 1990). Together, these observations suggest that many of the belugas that summer in Hudson Bay and James Bay may winter in Hudson Strait. However, neither bay has been thoroughly surveyed in winter. There are scattered reports of belugas wintering at the floe edge in northern and western Hudson Bay (Sutton and Hamilton 1932; Doan and Douglas 1953; Sergeant 1973; Reeves and Mitchell 1989a; Richard 1993a; McDonald et al. 1997), in Roes Welcome Sound (Finley et al. 1982), in the Belcher Islands (Freeman 1967, 1968; McDonald et al. 1997), near Long Island (M.J. Dunbar, McGill Univ., Montreal, QC, pers comm. 1993), near Peawanuck (McDonald et al. 1997) and in recurring leads and tide cracks in James Bay (Jonkel 1969; Schwartz 1976; McDonald et al. 1997). Whether these whales are part of a resident population(s) or are just trapped individuals that would normally winter in Hudson Strait is not known, but traditional knowledge studies suggest that a significant number of belugas winter in James Bay by choice (McDonald et al. 1997).

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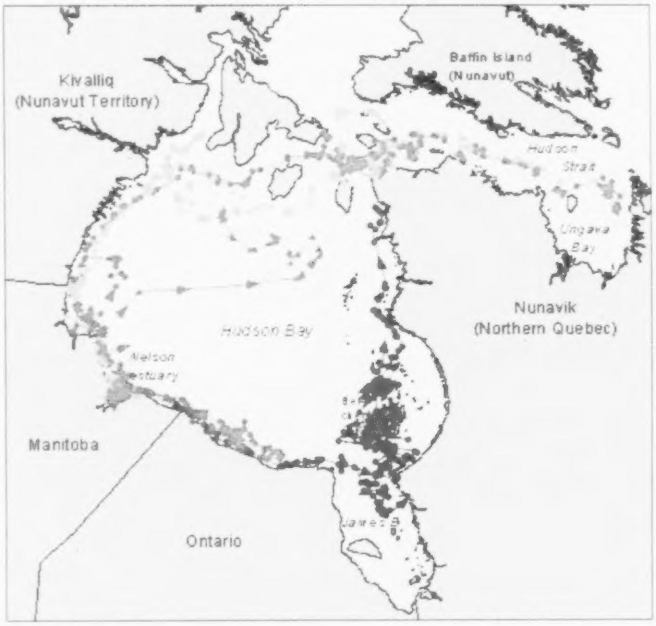

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The routes taken by belugas from wintering areas to summering areas in Hudson Bay and James Bay are not well known (Figure 9-2). Most knowledge of these routes comes from observations of the whale's arrival and departure times at traditional hunting areas, which are often near the coast (e.g., Finley et al. 1982; Reeves and Mitchell 1987; 1989a; McDonald et al. 1997). Ice leads can be important spring migration routes (Schwartz 1976; Stirling et al. 1981).

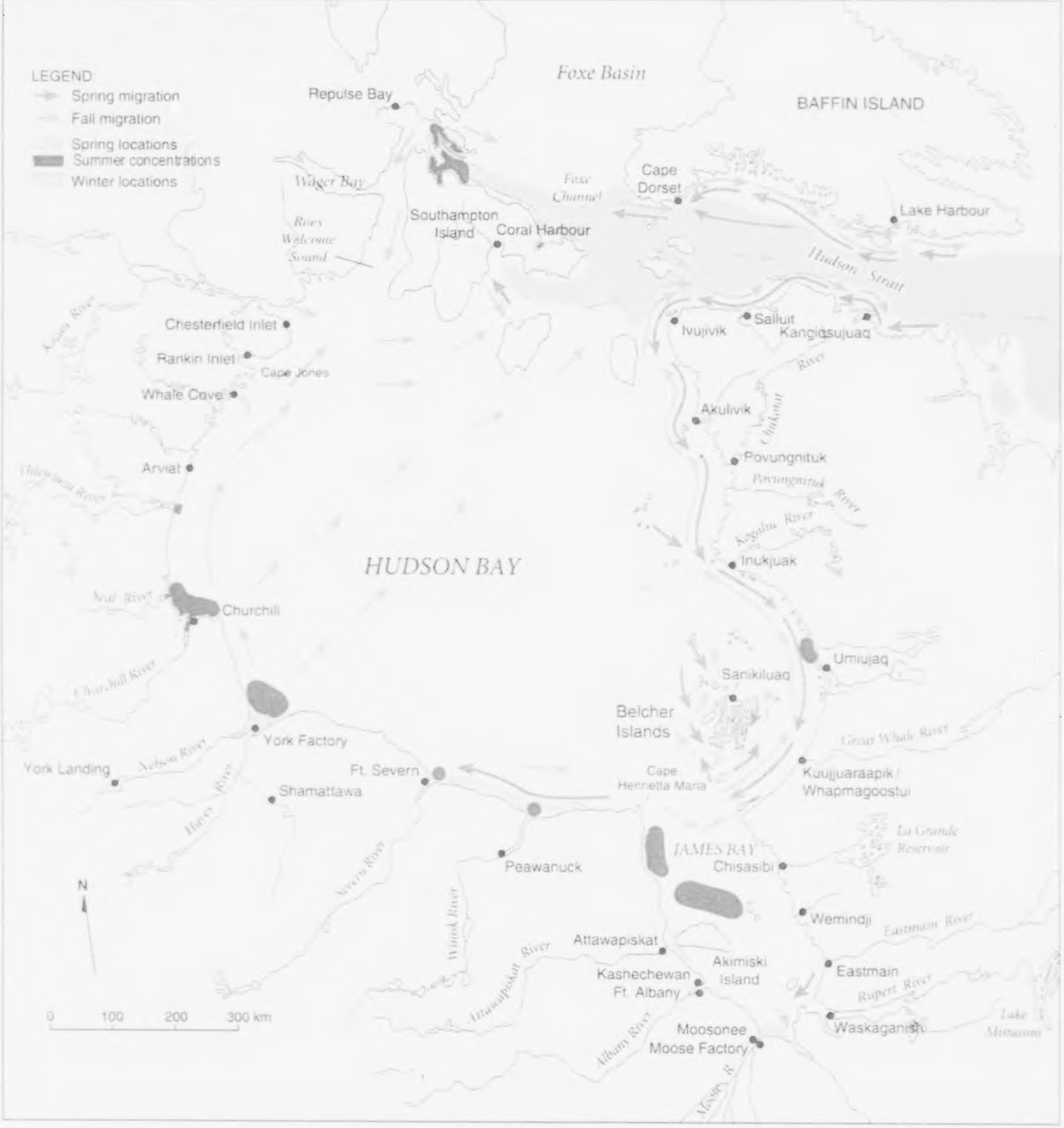

Figure 9-2. **Spring and fall movements of belugas and seasonal concentration areas compiled from traditional (McDonald et al. 1997) and scientific (Finley et al. 1982; Richard et al. 1990; Gosselin et al. 2002; Richard and Orr 2003; P. Richard, DFO, Winnipeg, pers. comm.) sources. Map modified from McDonald et al. (1997:88).**

Historical observations and traditional knowledge support the occurrence of a southward migration along the Quebec coast in spring and a return movement northward in the fall (Finley et al. 1982; Reeves and Mitchell 1987; McDonald et al. 1997). The earliest historical report of belugas at Akulivik was in April and the latest in October. To the south, at Petite rivière de la Baleine, Richmond Gulf (Lac Guillaume Delisle) and Grande rivière de la Baleine, they appear to have been uncommon before June and after mid-September. Inuit communities along the Quebec coast of Hudson Bay harvest most belugas from June through November (Finley et al. 1982; Lesage et al. 2001). Between 1990 and 2000, hunters from Kuujjuarapik, Umiujaq, and Inukjuaq killed most of their whales in July and August; hunters from Puvirnituk and Akulivik killed most of theirs in October; and those from Ivujivik killed most of theirs in June and October—not necessarily near the communities.

During the summer, belugas move along the Quebec coast of Hudson Bay but do not concentrate at the river mouths between Ivujivik and Inukjuak (M. Allard, Makavik Corp., Lachine, pers. comm.). An aerial survey of southeast Hudson Bay in 1985 found concentrations of belugas along the coast at Richmond Gulf, the estuaries of the Nastapoka River and Petite rivière de la Baleine, and offshore in the triangle formed by the Nastapoka River, the Belcher Islands, and Inukjuak (Smith and Hammill 1986). While whales were seen in the same general area during surveys conducted in 1993 (Kingsley 2000) and 2001 (Gosselin et al. 2002), fewer whales were seen offshore or in the estuaries. The highest herd counts in the Nastapoka River estuary in the summers of 1983 and 1984 by land-based observers were 245 and 260 whales, respectively (Caron and Smith 1990), but during tagging studies over a 3 week period in 1998 and a one month period in 1999 the maximum counts were less than 25 animals (Hammill and Doidge in Bourdages et al. 2002:11). Breton-Provencher (1979; Simard et al. 1980) also observed belugas along the southeast coast of Hudson Bay from Pointe Louis XIV to Richmond Gulf and in the Gulf itself. Historically, there were also large summer concentrations of belugas at Grande rivière de la Baleine (Reeves and Mitchell 1987, 1989b), but they have not been reported in recent years.

Studies of belugas radio-tagged at Petite rivière de la Baleine and the Nastapoka River have found that they remain offshore in eastern Hudson Bay, occasionally returning to the rivers, from August through late September (Smith 2000a). One animal, with a longer-lasting tag, was moving north past Puvirnituq when the signal was lost on 21 October. A female beluga with a calf was tagged at the Nelson River estuary in early August 2003. This animal moved to the Belchers in late August, remained there until mid-November, and then travelled north offshore the Quebec coast (Figure 9-1). It left the archipelago in mid-November and had reached the Kovik Bay (61°33' N, 77° 40' W) area when the signal was lost in late November.

Inuit in the Belcher Islands report that belugas arrive in spring both from the north and south (P. Kattuk, Mayor of Sanikiluaq, pers. comm.), suggesting that the whales either follow different routes from the north or that some of them winter south of the islands. Some of these whales, like the female and calf mentioned earlier, arrive at the Belchers via the Nelson River and northern James Bay (Richard and Orr 2003). It is not known whether whales summering in western Hudson Bay pass through southeast Hudson Bay or James Bay in spring.

There are historical reports of belugas occurring throughout James Bay and of their entering the shallow mouths of all the larger rivers along its coast (e.g., Trout Creek and the Attawapiskat, Moose, Albany, Hurricana, Trout, Pontax, Eastmain, and La Grande rivers; see review by Reeves and Mitchell 1987). In August 2001, they were distributed throughout the bay and quite numerous, particularly in the central area and along the Ontario coast north of 54°N (Gosselin et al. 2002). They feed at Hannah Bay and near Moose Factory in October and appear at Moose Factory and Attawapiskat as soon as there is open water in the spring (late March and April) (McDonald et al. 1997).

Belugas arrive at estuaries along the Ontario coast in early July (Johnston 1961; Richard et al. 1990). Cree have seen them in estuarine leads at Winisk and Ft. Severn earlier in the spring, before a shore lead has appeared, but this may not be a regular occurrence (Johnston 1961). During the summer, belugas move along the Ontario coast in small groups with concentrations entering the estuaries of larger rivers on the rising tide. Cree report that belugas begin to disappear from the Ontario coast about the end of August, moving off northward along the coast. This observation is supported by tagging studies that followed eastward movements along the Ontario coast by 2 of 5 belugas tagged at the Nelson in early August 2003 (Richard and Orr 2003). By mid-August, one had moved east into James Bay; the other travelled to the Winisk area and returned to the Nelson by early September.

Belugas arrive at estuaries in Manitoba during or immediately after spring break-up (late May or early June in the Hayes and Nelson, mid to late June in the Churchill and Seal) and generally leave by late August or early September (Reeves and Mitchell 1989a). The largest single concentration of belugas in the world occurs in summer in the area of the Nelson River estuary, and there are smaller but still substantial concentrations of whales at the estuaries of the Churchill and Seal rivers (Richard et al. 1990). The population of belugas that summers in western Hudson Bay between Arviat, Nunavut and the Manitoba border was estimated to number over 23,000 animals in July 1987 (Richard et al. 1990). This estimate did not correct for submerged animals and is likely conservative. Belugas were present at least 160 km offshore from the mouth of the Nelson River and their densities were highest near the river mouth. Over the course of the summer some animals tagged at the Nelson range east into James Bay and north to the Belchers, while other remain close to the estuary or move west towards Churchill (Richard and Orr 2003). Belugas are present in the Churchill River estuary from mid-June until the end of August and their numbers are greatest from late July through mid-August (Bernhardt 1999a). Most whales leave the estuary and move northward along the Kivalliq coast in late August and early September when the weather begins to get stormy (Doan and Douglas 1953; Sergeant 1973, 1981; Watts and Draper 1988). Animals tagged at the Seal River have been recovered at Whale Cove and Repulse Bay (Sergeant 1973, 1981).

Many belugas move west along the south coast of Southampton Island in May and June (Eecherk in Finley et al. 1982) but relatively few are seen along the northwest coast of Hudson Bay until late summer. This suggests that most belugas moving south in the spring do so beyond view of the ice edge in western Hudson Bay. The southern Kivalliq communities hunt belugas earlier in the season (July-August) than do those to the north (August-September) (Gamble 1988; see also Chapter 14). This suggests there is a northward movement of belugas along that coast in late summer, and is supported by Inuit traditional knowledge (McDonald et al. 1997). Inuit have also observed an eastward movement of belugas south of Coral Harbour in September (Eecherk in Finley et al. 1982). Belugas are present in the Repulse Bay area during August and September (Gamble 1988).

In 2003, radio-tagging studies showed that some animals move north of Churchill later in the season, in mid-September or early October, and travelled offshore the Kivalliq coast or across central Hudson Bay (Figure 9-1). They passed south of Southampton Island or Coats Island in mid- to late October, and all three of the animals whose tags were still transmitting in November continued east, reached eastern Hudson Strait and northern Ungava Bay by late November. One of these tags was still operating in early January 2004, and transmitting the beluga's location near Cape Chidley (P. Richard, DFO, Winnipeg, pers. comm. 2004).

9.1.2 Biology

Belugas are well adapted for cold and ice. They have thick insulating blubber and skin, no dorsal fin, and are capable of breaking ice up to 20 cm thick with their melon or dorsal ridge to open breathing holes (Freeman 1968; Sergeant 1973; Finley and Renaud 1980; Mitchell and Reeves 1981). The beluga is not a fast swimmer, with maximum burst estimated at 20 km·h^{-1} and normal cruising speeds in the range of 6-9 km·h^{-1}, but it is very agile in the water (Brodie 1989). Individuals can submerge for 15 to 20 minutes, swim 2 or 3 km underwater, and dive to depths of 647 m (Seaman and Burns 1981; Ridgeway et al. 1984; Reeves and Mitchell 1989b; Martin and Smith 1992). They can remain underwater for up to 42% of any 24 h period (Martin and Smith 1992). Their ability to remain submerged for long periods makes it difficult to estimate their numbers.

Aggregations of whales in the estuaries may be related to moulting or neonate survival. The animals generally ascend the estuaries with the rising tides and descend with the falling tides (Johnston 1961; Finley et al. 1982; Baker 1989). Active abrasion of skin surfaces softened by exposure to warm fresh water is thought to accelerate the moult, which is linked to a seasonal endocrine cycle and, unlike other cetaceans, synchronized to meet the energetic demands imposed on the whales by their environment (St. Aubin and Geraci 1989; St. Aubin et al. 1990; Watt et al. 1991; Smith et al. 1992, 1994). The presence of many females with newborn calves suggests that estuaries are important in the reproductive scheme of the belugas (Finley et al. 1982). It may be related to predator avoidance by females with calves at a time when they cannot find refuge in ice from killer whales (P. Richard, DFO, Winnipeg, pers. comm. 2003).

At the Nastapoka River estuary the aggregation is composed mainly of adult nursing females and their calves and older female offspring (Smith et al. 1994). In the summer of 1984 the ratio of adult male to adult female belugas in the Nastapoka River estuary was estimated at 1:4.3 (Caron and Smith 1990). Judging from behavioural observations (T. Smith pers. comm. in St. Aubin and Geraci 1989) and examination of stomach contents, very little feeding activity occurs while whales are in the estuary. When disturbed by hunts or motor traffic the whales left the estuary for periods of 40 and 24 h respectively. Belugas communicate using a variety of sounds and have well-developed hearing and echolocation abilities (Stewart and Stewart 1989).

Animals that summer in western Hudson Bay are smaller than those in Cumberland Sound and the high Arctic, but not different from eastern Hudson Bay or Ungava Bay stocks (Sergeant and Brodie 1969; Finley et al. 1982; Doidge 1990; Stewart 1994). At Arviat, the mean lengths and weights of belugas aged 10 years or older were (Stewart and Walker 1987):

	n	Length (cm) ± SE	n	Weight (kg) ± SE
male	40	376.1 ± 17.4	39	679.4 ± 107.3
female	19	329.7 ± 20.1	18	488.7 ± 85.1

Assuming that belugas in western Hudson Bay deposit two dentine layers on their teeth annually (Brodie 1982), they may live at least 25 years (Sergeant 1973) while those in southeast Hudson Bay may live at least 33 years (Doidge 1990). The females reach sexual maturity at a mean age of 5 years and give birth to a single calf after a gestation period of about 14 months (Sergeant 1973). Breeding likely peaks in April or May (Richard 1993a), and calving takes place from May to early August--peaking in late May in northern Quebec and late June in western Hudson Bay (Reeves 1994). Calves are nursed for about 20 months and pregnancy occurs about once every 3 years. Newborn belugas are dark brown, grey brown, or blue grey and become progressively lighter in colour as they mature (Stewart and Stewart 1989).

Capelin, estuarine fishes, squid, decapod crustaceans, and annelid worms (*Nereis* sp.) are important food items for adult belugas summering in Hudson Bay (Sprules 1952; Doan and Douglas 1953; Breton-Provencher 1979; Simard et al. 1980; Watts and Draper 1986; McDonald et al. 1997). Belugas in the Belchers will also eat sculpins (P. Kattuk, Mayor of Sanikiluaq, pers. comm.), and young belugas that are just cutting teeth will eat *Nereis* sp. (Doan and Douglas 1953). While the capelin is an important food of belugas in southern Hudson Bay (Doan and Douglas 1953; Watts and Draper 1986) its' abundance varies from year to year (Sergeant 1973).

Predation by killer whales, hunting by man, and entrapment by ice are important causes of beluga mortality (Mitchell and Reeves 1981; Reeves and Mitchell 1988). Polar bears also prey on belugas to a limited extent (Freeman 1973; Smith 1985; Smith and Sjare 1990).

9.1.3 Population Status and Protection

Aerial systematic line transect surveys and coastal surveys were conducted in the summers of 1993 and 2001 to estimate the number of belugas at the surface in offshore areas of eastern Hudson Bay and James Bay (Table 9-1). The results of these surveys were analysed using both line transect and strip transect methods to facilitate comparison of the data among years, and with data from strip transect surveys that followed the same tracks in 1985. From 1985 to 2001, the number of belugas summering in James Bay increased fourfold, while numbers in eastern Hudson Bay declined by almost half (Gosselin et al. 2002). These estimates did not correct for animals submerged beyond view and may be conservative. While the 2001 estimate for eastern Hudson Bay was similar to that from 1993, it would have been substantially lower (i.e., the line transect estimate would decrease from 1194 to 816) if a single group of 52 whales had not been seen on transect.

The apparent rate of increase in the James Bay beluga population cannot be explained on the basis of reproduction alone (Bourdages et al. 2002; Gosselin et al. 2002). It may reflect, at least in part, the fact that the 1985 survey (Table 9-1) was flown earlier in August, when a lot of ice still remained in northwest James Bay (Kingsley 2000). In 1993 and 2001 surveys, the highest densities of whales were seen in this area. Alternatively, there may have been immigration of animals from Hudson Bay. This latter hypothesis is supported by the timing of migration of the tagged female beluga into James Bay (Richard and Orr 2003) and the fact that people at Attawapiskat say that belugas are more numerous there in late August (P. Richard, DFO, Winnipeg, pers. comm.). This has important implications for population management and argues the need to improve understanding of the relationships between animals in these areas.

Table 9-1. **Indices of abundance for beluga populations in eastern Hudson Bay and James Bay (from Gosselin et al. 2002).**

Year	Abundance estimate				Original reference
	Eastern Hudson Bay		James Bay		
	Strip transect N (SE)	Line transect N (SE)	Strip transect N (SE)	Line transect N (SE)	
1985	1,442 (165)	2,089 [a]	1,213 (290)	1,842 [a]	Smith and Hammill 1986
1993	706 (205)	1,032 (421)	2,296 (566)	3,141 (787)	Kingsley 2000
2001	659 (263)	1,194 (507)	4,732 (712)	7,901 (1744)	Gosselin et al. 2002

a = Data collected in 1985 did not allow a line transect analysis, so the value is the product of the strip transect estimate and the mean ratio of line/strip transect estimates for the given stratum for the two following surveys.

The surveys indicate that the number of animals in eastern Hudson Bay has decreased both in offshore areas and in the estuaries since 1985. During this period there has also been a decline in the mean age of the catch, from a median of 13 years (n = 132, in 1980+1983-87) to a median of 8.7 years (n = 108; in 1993-01)(Lesage et al. 2001:25; DFO 2002a:6). Recent harvests are also characterized by an absence of older animals. In the 1980-87 the oldest animal harvested from Nunavik was 34 y; in 1993-99 the oldest animal harvested from eastern Hudson Bay was 18 y. These data, and the observation that fewer animals have been frequenting the Nastapoka River estuary in recent years relative to the 1980's and early 1990's, suggests that the population in eastern Hudson Bay continues to decline (Gosselin et al. 2002). The vulnerability of animals that summer in eastern Hudson Bay to harvest elsewhere is unknown but genetic studies suggest that hunters from Sanikiluaq and communities in Hudson Strait harvest some (de March and Postma 2003). If few of the animals harvested by Sanikiluaq (~13%) belong to the eastern Hudson Bay population, then few of those seen by aerial surveys around the Belchers are likely to belong to that population. This suggests that the eastern Hudson Bay beluga population may be smaller and more vulnerable than the aerial survey data suggest (Hammill 2001; Hammill et al. 2004). The 2001 management plan for the Northern Quebec (Nunavik) belugas recommended a limit of 30 on the annual harvest of belugas from eastern Hudson Bay (EHB) (DFO 2002a). DFO has cautioned that continuing current levels of harvesting (>140 EHB beluga killed in 2001 by communities in Hudson Bay and Hudson Strait) could cause this population to disappear within 10 to 15 years (Hammill 2001; Bourdages et al. 2002).

On 21 July 1987, DFO made an aerial reconnaissance survey of coastal waters from Kaskattama River, Manitoba to Cape Henrietta Maria, Ontario for belugas (Richard et al. 1990). Two transects were flown parallel to the coast, one 3 km and the other 28 km off shore. Observers saw 1269 belugas on the first transect, of which 232 were concentrated at the Severn River estuary and 393 at the Winisk River estuary. Only 30 belugas were seen on the offshore transect.

The number of belugas in the area of the Nelson River estuary on 19 July 1987 was estimated from a systematic aerial visual and photographic survey at 19,500 (95% CI 14,200-26,800) animals (Richard et al. 1990). A survey of the Churchill River-Seal River area on 15 July 1987 produced a mean estimate of 5,600 belugas (95%CI 4,100-26,000). Tagging studies indicate that the whales can move between these estuaries in less than 5 days (Weaver in Richard et al. 1990), which raises the possibility some may have been double-counted. However, a survey of the two areas on consecutive days, 17 and 18 July 1987, yielded an estimate of 23,000 belugas (95% CI 14,200-26,800). The surveys on the 17th and 18th did not cover offshore areas of the Nelson River estuary that were covered on the 19th, and none of the estimates was adjusted to compensate for whales that were submerged beyond view. The beluga population in western Hudson Bay was thought to be stable at current levels of removal (Richard 1993). It has not been resurveyed since 1987.

Aerial reconnaissance surveys conducted in 1981 along the Kivalliq mainland coast north of the Manitoba border saw only 62 belugas in late July; when the area was resurveyed in August this number rose to 329, including a herd of 128 animals at the mouth of the Thlewiaza River (Richard et al. 1990). Small concentrations of belugas have also been observed at the mouths of the Tha-anne and Wilson rivers (Brack and MacIntosh 1963).

Systematic aerial visual and photographic surveys of belugas in Repulse Bay-Frozen Strait area of northern Hudson Bay in late July of 1982-84, yielded mean estimates of 700 (95%CI 200-3,300) to 1,000 (95%CI 621-1,627) whales (Richard et al. 1990). A herd of 143 belugas was seen south of the survey area on 23 July 1983 in the Canyon River estuary of south Southampton Island; another herd of 685 animals was seen at the head of East Bay on 17 August 1988. These observations suggest that a population of over 1000 animals summers in northern Hudson Bay. It is not known whether these whales represent a separate stock. Belugas were not seen during similar aerial surveys of Roes Welcome Sound in March 1982.

The beluga is listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) which allows regulated trade under permit (Stewart and Stewart 1989). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has designated the eastern Hudson Bay beluga population "Endangered", and the western Hudson Bay population as "Special Concern" (Smith 2004): the former on the basis that it continues to decline and is likely to disappear at current hunting levels in less than 10 to 15 years; the latter on the basis that it has not been surveyed for 15 years, may consist of more than one population, and is subject to substantial removals by hunting. Shipping and hydroelectric projects may also pose threats to both populations. The effects of hunting and development on the beluga populations in Hudson Bay and James Bay are discussed in Chapters 14 and 15, respectively. There is a well-developed tourist industry in Churchill, and to a much lesser extent at communities and lodges along the Kivalliq coast, that caters to beluga whale-watchers.

9.2 NARWHAL *Monodon monoceros* Linnaeus, 1758

Narwhals are medium-sized toothed whales that lack a dorsal fin. They are about 1.60 m long at birth (80 kg). Males can grow to 5.40 m (~1935 kg) and females to 4.94 m (~1552 kg). Adult narwhals have only two teeth. In most males, the right tooth remains embedded in the skull and the left forms a magnificent spiral tusk that can extend straight forward over 3 m. In most females, both teeth remain embedded in the maxillae. Inuit use a variety of descriptive words in Inuktitut to identify narwhal. These include *tuugaalik* (with tusk), *qirniqtaq qilalugaq* (black whale), and a*llanguaq* (with black and white dots) (J. Kilabuk, Pangnirtung, pers. comm. 2002).

Narwhals inhabit Arctic waters and are seldom seen south of 61°N (Figure 9-3). They are common in the waters of Nunavut, west Greenland, and the European Arctic but rare in the East Siberian, Bering, Chukchi, and Beaufort seas. This distribution appears to be unchanged from historical reports.

Two populations of narwhals have been recognized for the purpose of hunt management in Canada (DFO 1998a+b). This tentative separation into Baffin Bay and Hudson Bay populations is based largely on summering distribution. It is supported by recent studies that found whales taken by Repulse Bay to have molecular genetics and organochlorine contaminant profiles that were distinct from those of animals harvested at several High Arctic locations (de March et al. 2003; de March and Stern 2003). Narwhals that summer in northwest Hudson Bay are believed to winter in eastern Hudson Strait (Richard 1991). They range over an area of roughly 250,000 km² (Stewart 2004a). Narwhals from the Baffin Bay population summer in the waters of West Greenland and the Canadian High Arctic and winter in Baffin Bay and Davis Strait (Koski and Davis 1994; Dietz et al. 2001; Heide-Jørgensen et al. 2003). The population affinity of animals that summer north of Baffin Bay and along the eastern and southern coasts of Baffin Island is unknown.

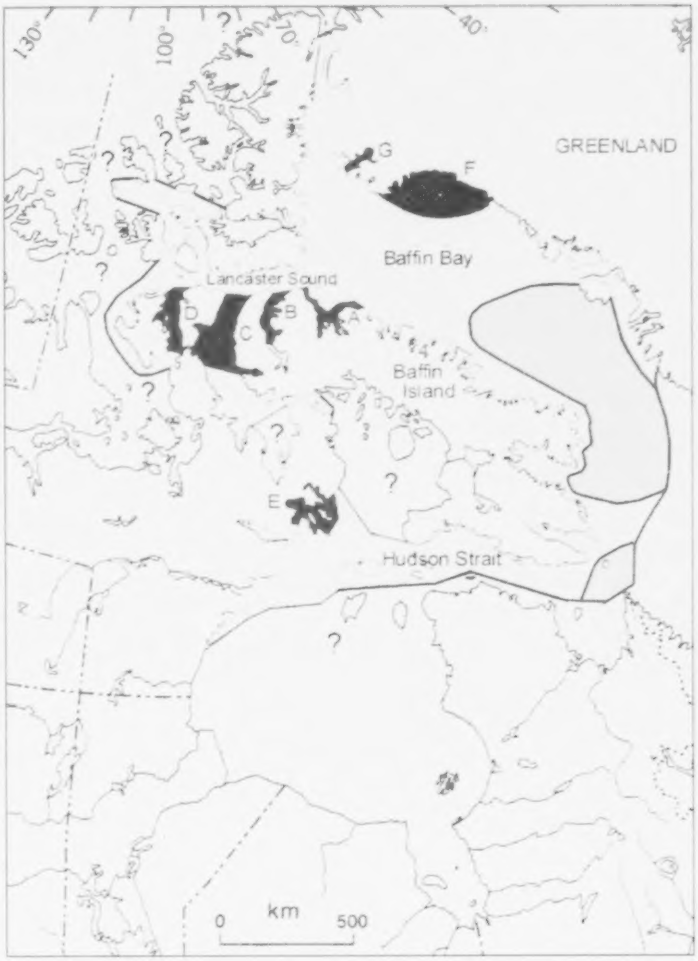

Figure 9-3. **Distribution of narwhals in Canada (from Stewart 2004a). Summer concentrations in solid black include: A. Eclipse Sound/Navy Board Inlet, B. Admiralty Inlet, C. Prince Regent Inlet, D. Peel Sound, E. Foxe Channel, F. Melville Bay, and G. Inglefield Bredning. Wintering concentrations are shown in medium grey and known range in pale grey. Question marks indicate areas where the extent of the narwhal's distribution is uncertain.**

9.2.1 Distribution and Movements

The summer range of the Hudson Bay narwhal population includes the waters surrounding Southampton Island, with the largest aggregations in Repulse Bay, Frozen Strait, western Foxe Channel and Lyon Inlet (Richard 1991; Gaston and Ouellet 1997; DFO 1998a; Gonzalez 2001; P. Richard, pers. comm. 2002). The area of these summering grounds is roughly 17,000 km² (Stewart 2004a). Whales from this population also summer, typically in smaller numbers, in Wager Bay and Duke of York Bay. There are no indications of large summer aggregations elsewhere in Hudson Bay or in James Bay, Hudson Strait or southern Foxe Basin. Sightings of narwhals to the south near Arviat and east near Cape Dorset are unusual and have been attributed to the presence of killer whales (*Orcinus orca*) (Higgins 1968; W. Angalik, pers comm. in Stewart et al. 1991). Thorough searches of the historical literature for the Quebec coast of Hudson Bay and James Bay have not found reports of narwhals (Reeves and Mitchell 1987), but three dead animals have been found along the Ontario coast of Hudson Bay (Johnston 1961).

Scientific studies have not identified any large-scale changes in the seasonal distribution of narwhals, but Inuit have observed local changes. Since the 1960s, narwhals have become less common near the hamlet of Repulse Bay. Hunters attribute this change to an increase in the number of people hunting and traveling with motorboats and snowmobiles near the community (Gonzalez 2001).

The seasonal movement patterns of the Hudson Bay narwhals are not well known. In the spring, they likely migrate westward from putative wintering grounds in eastern Hudson Strait (Richard 1991; Koski and Davis 1994), traveling offshore through Hudson Strait and Foxe Channel until they reach the floe edge east of Repulse Bay in late June (Gonzalez 2001). They move into their summering grounds in western Foxe Channel, Frozen Strait, Lyon Inlet and Repulse Bay as ice conditions permit and typically remain until late August or early September, when they travel southeastward out of the area through Frozen Strait, following the east coast of Southampton Island. Narwhals are seldom seen west of Southampton Island or along the west coast of Hudson Bay unless killer whales are present, but they are seen on occasion at the floe edge near Coral Harbour in late June or early July, and in late August or early September. Some animals also winter in open leads and polynyas of northern Hudson Bay and western Hudson Strait (Sutton and Hamilton 1932; Richard 1991).

Narwhals from the Hudson Bay population are not known to move north of Lyon Inlet (Richard 1991; Gonzalez 2001) but observations of whales passing east of Igloolik Island on their way north to Fury and Hecla Strait (Stewart et al. 1995), suggest that there may be some northward movement of narwhals into the region. It is also possible that these whales are resident in the region or are members of the Baffin Bay population returning northward. Tagging studies have not followed whales from the Hudson Bay population between their summer and winter habitats or whales from the Igloolik area to their wintering habitat.

The timing of narwhal migrations can vary by a month or more from year to year, depending upon ice conditions. They generally travel in groups (pods) of <10 animals that are dispersed during localized movements in summer, but gather into concentrations of many hundreds of animals during directed migrations in the spring and fall (Silverman 1979; Koski 1980a; Guinn and Stewart 1988; Cosens and Dueck 1991; Koski and Davis 1994; Richard et al. 1994). Most migratory movement takes place at the surface and their swimming speed averages 5.0 $km \cdot h^{-1}$ whether they are traveling horizontally or diving vertically (Heide-Jørgensen et al. 2001). Narwhals can reach peak speeds of 20 $km \cdot h^{-1}$ (Richard 2001).

9.2.2 Biology

Narwhals inhabit a vast area of the Arctic, but little is known of their actual habitat requirements. In summer, they prefer coastal areas that offer deep water and shelter from the wind (Finley 1976; Kingsley et al. 1994; Richard et al. 1994). During their fall migrations in the High Arctic, and later while wintering in the pack ice, narwhals prefer deep fjords and the continental slope, where depths range from 1000 to 1500 m and upwellings may increase biological productivity (Dietz and Heide-Jørgensen 1995; Dietz et al. 2001). They frequent heavy pack ice for much of the year and follow leads in the ice to their summering grounds. The quality of the ice habitat, particularly the presence of leads in fast ice and the density of broken pack ice, appears to influence habitat selection (Koski and Davis 1994). The ice may also provide refuge from predation by killer whales. Little is known of the physiological requirements of narwhals or of the species' ability to adapt to change in its environment (Stewart 2004a).

The vital rates of narwhals are uncertain because there is no accurate method to determine their ages. By analogy with belugas, females are believed to mature at 5 to 8 years and produce their first young at 7 to 13 years (Braham 1984; Kingsley 1989). Mating peaks in mid-April, and most calves are produced in July and August after a gestation period of 14 (Best and Fisher 1974) to 15.3 months (Hay 1984). However, there are few newborn calves at the Repulse Bay ice edge in July (Gonzalez 2001). While more frequent reproduction is possible, mature females produce a single calf about every three years on average until perhaps 23 years of age (Hay and Mansfield 1989; Kingsley 1989). Longevity may be about 50 years, but most animals probably do not reach the age of 30. Generation times and net recruitment rates for narwhals are unknown. Rates of mortality from hunting and from predation by killer whales and polar bears are unknown.

The potential for large-scale mortality due to entrapment by ice or to disease is also unpredictable. Narwhals from the Hudson Bay population have been trapped by ice in Lyon Inlet (Degerbøl and Freuchen 1935), near White Island, and in Ross Bay (66°52'N, 85°00'W)(Gonzalez 2001). Few large entrapments have been reported from Canadian waters. When these entrapments occur early in the winter the mortality rate is likely high but the survival rate of animals trapped later in the season may be good, provided they are not hunted or found by bears. Little is known of the diseases of narwhals and their response to pathogens.

The rate of predation on narwhals by killer whales and polar bears is unknown but may be significant. Hunters in the Repulse Bay area see killer whales more frequently now than in the past and have expressed concern about their predation on narwhals (Gonzalez 2001). Killer whales may have driven narwhals close to Cape Dorset in the 1960s (Higgins 1968), south to Arviat in 1988 (W. Angalik, pers. comm. in Stewart et al. 1991), and into shallow water in the Repulse Bay area in 1999 (Gonzalez 2001). The latter resulted in an unusually large harvest of narwhals by Repulse Bay (see Tables 14-4 and 14-5). Killer whales also made hunting narwhals easier in the Repulse Bay area in 1998, and in the Lyon Inlet area in 2000. Their kill of narwhals during these high-harvest years is unknown but possibly significant.

Narwhals eat fishes and invertebrates (Degerbøl and Freuchen 1935; Vibe 1950; Finley and Gibb 1982; Neve 1995). The composition of their diet varies with season and location, likely in response to dietary preferences and the seasonal or geographical availability of prey species (Neve 1995). They appear to feed year-round but may increase their food intake prior to migration (Remnant and Thomas 1992; Stewart et al. 1995). Their primary summer foods in the Canadian Arctic are Arctic cod (*Boreogadus saida*), Greenland halibut (*Reinhardtius hippoglossoides*), squid (*Gonatus fabricii*), and decapod crustaceans (Finley and Gibb 1982; Hay 1984). Inuit hunters have also found Greenland cod (*Gadus ogac*) in narwhal stomachs (Stewart et al. 1995) and report that they eat Arctic charr (*Salvelinus alpinus*) (Remnant and Thomas 1992). Little is known about the interactions between narwhals and other species for food and habitat. Their preference for deepwater habitat effectively separates them from belugas for much of the summer.

Narwhals make a variety of sounds and are sensitive to underwater noise (Reeves 1977; Ford and Fisher 1978; Ford 1987; Miller et al. 1995). They can detect approaching ships at a distance of 80 km and show behavioural responses at distances of 55-40 km (Finley and Davis 1984; Miller and Davis 1984; Cosens and Dueck 1988, 1993; Finley et al. 1990). Inuit hunters have observed that narwhals are sensitive to, and avoid, noise from machines and explosions (Gonzalez 2001).

The narwhal's ability to dive deeply and remain under water for long periods enables them to move long distances under water to avoid hunters and to locate areas where they can surface to breathe. In the deep waters of Baffin Bay, narwhals dive to at least 1500 m and daily make dives to depths of over 500 m (Heide-Jørgensen and Dietz 1995; Heide-Jørgensen et al. 2002). They can remain under water for at least 26.2 minutes when foraging (Laidre et al. 2002) and up to 30 minutes when pursued by Inuit (Gonzalez 2001). Their diving behaviour makes it difficult to obtain accurate population estimates.

9.2.3 Population Status and Protection

A good estimate of the initial size of the Hudson Bay narwhal population cannot be generated from historical harvest data (Mitchell and Reeves 1981; Reeves 1992a). Estimates of current population size have been limited to methods that only estimate a portion of the population. Richard (1991) conducted systematic visual and photographic aerial surveys of narwhals in the Repulse Bay area between Roes Welcome Sound and Lyon Inlet, north of Southampton Island in March 1983 and July of 1982, 1983, and 1984. These surveys included the major known summering concentrations of the Hudson Bay narwhal population. The July 1984 photographic survey was repeated in August 2000, with the addition of northern Lyon Inlet and Foxe Channel (P. Richard, DFO, Winnipeg, pers. comm. 2002). Without correcting the results of either survey for submerged animals, or the latter survey for persistent fog or animals that may have occupied Wager Bay (Gonzalez 2001), the narwhal population was estimated at 1355 (90%CI = 1000-1900) animals in 1984 and 1780 (90%CI = 1212-2492) animals in 2000. While the latter result is preliminary it suggests that the population did not decrease between surveys despite concern over heavy exploitation in 1999 (Stewart 2004a).

Narwhal populations in Canada may be limited by hunting, environmental contaminants (see Chapter 16), climate change, and industrial activities such as commercial fishing and vessel traffic (Stewart 2004a). The effects of climate change on ice habitats used by narwhals are uncertain, as is the species' capacity to adapt (see Chapter 17). The effects of the other factors are mitigated by the species' deepwater habits and widespread geographical distribution, much of which is outside normal hunting areas in offshore pack ice and in isolated areas of the Arctic. This remote distribution protects many narwhals from hunters as well as isolated oil spills or other events. However, under exceptional circumstances, such as large ice entrapments or when killer whales drive narwhals into shallow water, many animals can be taken at once from a single locality. Hunting probably represents the most consistent factor limiting the Hudson Bay narwhal population (see Chapter 14).

Protection for narwhals in Canada is limited to measures that manage the hunt, live capture, and movement of narwhal products (Stewart 2004a). The species is listed in Appendix II of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES). This designation is reserved for species that could be threatened with extinction if trade is not controlled and monitored. It means that a CITES export permit is required for narwhal products that cross international boundaries. In Canada, these permits are administered by DFO. In 1996, the International Union for the Conservation of Nature and Natural Resources (IUCN) assessed the population status of the narwhal (Hilton-Taylor 2000). It concluded that the threat of extinction could not be adequately assessed with the data available and listed narwhal in the data deficient (DD) category in *The 2000 IUCN Red List of Threatened Species*. In November 2004, the Committee on the Status of Endangered Wildife in Canada (COSEWIC) designated narwhals as a species of "Special concern", based on an updated review of their status (Stewart 2004a).

9.3 KILLER WHALE *Orcinus orca* (Linnaeus, 1758)

These powerful, fast-moving members of the dolphin family have distinctive black, white and grey markings and a tall, wide dorsal fin (Leatherwood and Reeves 1983; Heyning and Dahlheim 1988). They have a worldwide distribution limited only by ice cover, shortage of prey, and human predation. Killer whales are robust. Males generally attain a body length of 8.2 m and females 7.0 m (Mitchell 1975).

Little is known of their movements or biology in Hudson Bay and James Bay. They are seen infrequently and in small numbers in northern Hudson Bay and to the south along the Keewatin coast to Churchill and along the Quebec coast to Inukjuak in August and September (Doan and Douglas 1953; Sergeant 1968, 1986; Reeves and Mitchell 1988). Cree along the Ontario coast do not have a name for killer whale (Johnson 1961), suggesting that it is rare in James Bay and southern Hudson Bay.

Killer whales are top-level marine carnivores that eat fish, marine mammals, seabirds, and squid (Mitchell and Reeves 1982; Campbell et al. 1988; Heyning and Dahlheim 1988; Reeves and Mitchell 1988). When killer whales are nearby, belugas (W. Angalik, Arviat, pers. comm. 1989) and narwhals (Gonzalez 2001) hide in the shallows of estuaries or deep bays and seals leave the water (Johnson 1961), making them easy prey for hunters.

Killer whales are not hunted for food in the Hudson Bay area, but in August 1978, a killer whale that strayed into Baker Lake was killed by hunters offshore the community (S. MacDonald, Water Survey of Canada, Baker Lake, pers. comm. 1979; Sergeant 1986). COSEWIC is interested in the killer whale but does not consider the species to be of immediate concern (Campbell 1987).

9.4 BOWHEAD WHALE *Balaena mysticetus* Linnaeus, 1758

The bowhead or Greenland right whale is a large, slow-swimming Arctic baleen whale with a discontinuous circumpolar distribution (Leatherwood and Reeves 1983; Reeves and Leatherwood 1985). Based on the species' summer distribution there appear to be two stocks or populations in the eastern Canadian Arctic, one that summers in northern Hudson Bay and Foxe Basin and the other in Baffin Bay, Davis Strait and the waters of the Canadian High Arctic (Figure 9-4)(Cosens and Innes 2000). Genetic studies support the idea that the two stocks are distinct (Maiers et al. 1999). However, recent tagging and distribution studies that have demonstrated movement of animals between Prince Regent Sound and both Foxe Basin and Cumberland Sound suggest a single population (S. Cosens, DFO pers. comm.).

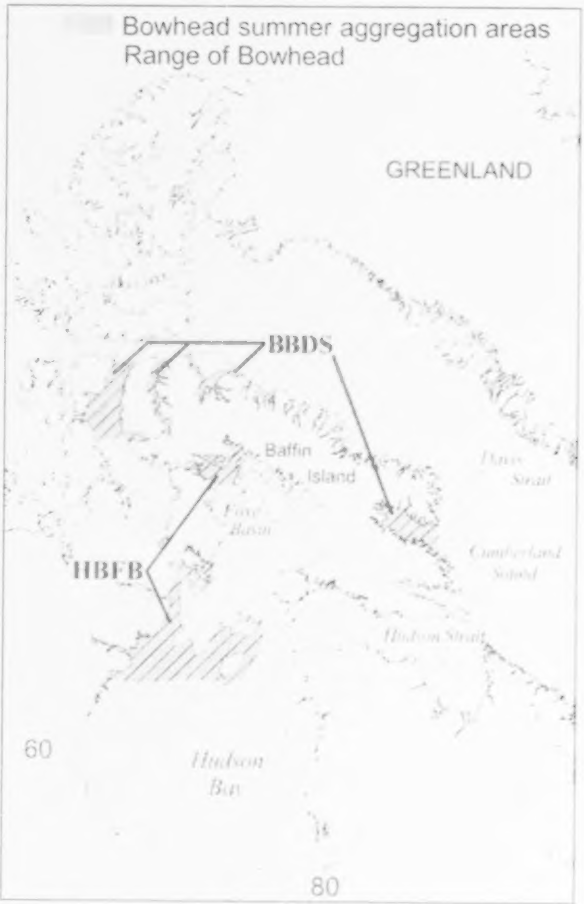

Figure 9-4. **Ranges and summer aggregation areas of the two putative stocks of bowhead whales in eastern Canadian Arctic waters (modified from Reeves and Cosens 2003:284). BBDS = Baffin Bay-Davis Strait stock; HBFB = Hudson Bay-Foxe Basin stock).**

9.4.1 Distribution and Movements

The movements and biology of bowheads in Hudson Bay and James Bay are not well known. Some animals have been seen in mid-winter at the floe edge in western Hudson Bay, and off Mansel Island and some of the islands in southeast Hudson Bay (Low 1906). Whether these whales represent a resident, winter population or were simply trapped by ice is not known. Reeves et al. (1983) suggest that the entire summer population of bowhead is unlikely to winter in the bay. They may winter at the southern edge of the pack ice in Davis Strait (Low 1906; Mansfield 1985) or in Hudson Strait (McLaren and Davis 1981, 1983), particularly in highly productive areas of mixed arctic and subarctic water. In the spring, they follow the receding pack ice to seek out the most productive waters in which to feed (Figure 9-5). Inuit from Repulse Bay report that they are concentrated at the floe edge in June but disperse after breakup and then gather inshore in August (NWMB 2000).

Early whalers observed that bowheads were present in eastern Hudson Strait in April and May and in western Hudson Strait in late May (Wakeham 1898; Low 1906). They could be found along the floe edge in northwest Hudson Bay on both sides of the southern entrance to Roes Welcome Sound in June and early July, and moved northward as the ice cleared, through the Sound to Repulse Bay and later through Frozen Strait into Foxe Channel. Most commercial kills in the area south of Roes Welcome Sound were made in June and July, while those in Frozen Strait and Repulse Bay were made in August and September (Ross 1974; Reeves et al. 1983; Reeves and Cosens 2003). Whalers believed that the bowheads returned eastward through Hudson Strait in late autumn. There is good agreement between their observations and those reported by Inuit elders and hunters (NWMB 2000). The predictable cycle of occurrence strongly suggests that there is a seasonal migration of bowhead between Hudson and/or Davis Strait and Hudson Bay.

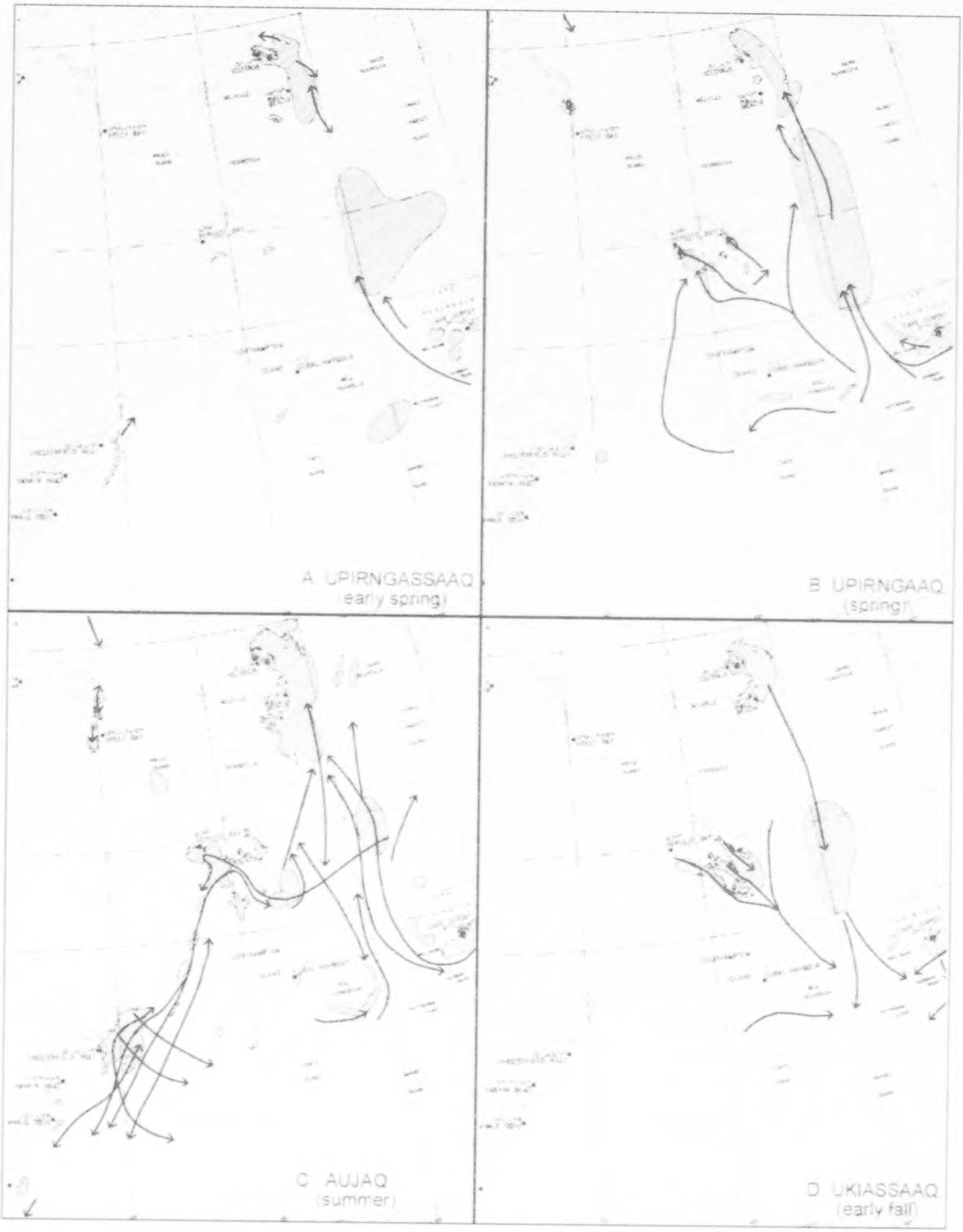

Figure 9-5. Inuit knowledge of the seasonal movements of bowheads in Hudson Bay and Foxe Basin from A. UPIRNGASSAAQ (early spring) to D. UKIASSAAQ (early fall) (adapted from NWMB 2000).

Historically, bowheads were concentrated in northwest Hudson Bay, between Marble Island and Frozen Strait (Ross 1974; Reeves et al. 1983; Reeves and Mitchell 1987). They were abundant in northwest Hudson Bay from mid-May through mid-September (Ross 1974; Reeves et al. 1983; Reeves and Cosens 2003). A favourite area for hunting them was the vicinity of Whale Point, north of the mouth of Chesterfield Inlet (Low 1906; Degerbøl and Freuchen 1935; Reeves et al. 1983). Bowheads are still seen in northwest Hudson Bay (Mansfield 1971; Cosens et al. 1997; Cosens and Innes 2000). They are not common to the south but have been seen at Arviat and in the Churchill River estuary in the 1980's (Watts 1988). Recent satellite telemetry studies have confirmed the movement of whales from Foxe Basin to Southampton Island in August (Dueck in Reeves and Cosens 2003).

The Ottawa Islands, in eastern Hudson Bay, may also have been an historical concentration area for bowheads (Degerbøl and Freuchen 1935). In 1912-13, the Scots whaler Active of Dundee took 6 whales and lost 4 in the Ottawas (Flaherty 1918; Newspaper Clipping in PAC, MG 29, A58, Vol 8., File 5 in Reeves and Mitchell 1987). Carcasses have also washed up on the beaches in the archipelago (Bell 1884; Flaherty 1918). They were, however, a novelty to local Inuit (Flaherty 1918). Manning (1976) saw a whale, or whales--presumably bowhead, blowing in the Ottawas in August 1971.

There are few confirmed reports of bowheads in James Bay and southeast Hudson Bay. On 24 August 1967, a large bowhead was seen at the surface 100 m offshore about 10 km south of Petite rivière de la Baleine (55°05'N, 76°52'W) (Fitzhugh in Reeves et al. 1983); a bowhead was seen northeast of Attawapiskat, James Bay, 1.6 km off Ekwan Point on 11 July 1978 (J. Crawford pers. comm. in Reeves et al. 1983); and, in 1981-2 residents of Kuujjuarapik purchased baleen on the Belcher Islands, probably from a bowhead--the whale was apparently killed in 1981 (C.A. Cote. pers. comm. in Reeves and Mitchell 1987).

9.4.2 Biology

Bowheads lack a dorsal fin and have an enormous head that can be up to one third of the total body length (Leatherwood and Reeves 1983). They exhale a characteristic V-shaped spout which is easily identified on a windless day, and seldom travel in groups of more than 6 animals. Individuals can grow to a length of about 20 m and a large animal may weigh 100 tonnes (Scoresby 1820; Nereini et al. 1984; Reeves and Leatherwood 1985). They have very thick, oil-rich blubber (up to 45 cm) that provides insulation from the cold Arctic water.

Age estimates based on aspartic acid racemization, which measures changes in the forms of aspartic acid in the eye lens over time, suggest that bowheads attain sexual maturity at about 25 years of age (age at length 12-13 m for males, 13-13.5 m for females) and may live over 200 years (George et al. 1999). Adult females are larger than males (Koski et al. 1993). Little is known of the species reproduction. Mating probably takes place in the spring, and calving from March through August of the following year--peaking in May. Calves are about 4.5 m long at birth and are usually born singly, although twins do occur (Nerini et al. 1984). The calving interval for the Hudson Bay/Foxe Basin population is unknown (DFO 1999a).

The Wager Bay-Marble Island area of northern Hudson Bay served as a nursery area for bowheads before commercial whaling reduced the population (Reeves and Cosens 2003), and photographic studies suggest that northern Foxe Basin currently is a nursery area (Cosens and Blouw 1999). Few whales now use the Wager Bay-Marble Island area (Reeves and Cosens 2003). It is not known whether this area was used by a separate stock that has not recovered from commercial whaling, or whether both were used by a single stock that has retreated northward. Females with calves were also taken historically in the Repulse Bay area (Reeves and Cosens 2003) and are still present (NWMB 2000).

Bowheads feed mainly by "skimming" small planktonic and benthic crustaceans from the water with their baleen (Lowry et al. 1978; Wursig et al. 1985), and often occur in areas where zooplankters, particularly calanoid copepods, are abundant relative to the surrounding waters (Scoresby 1820; Griffiths 1981). Feeding areas often correspond to oceanic fronts where temperature, turbidity, or current patterns suggest there is discontinuity or mixing (Finley et al. 1983; Borstad 1985). Their predictable concentration in these feeding areas made bowheads very vulnerable to capture, and still leaves them susceptible to disturbance by humans. Bowheads have a complex vocal repertoire and are sensitive to noise disturbances (Finley 2001). Predation by killer whales and suffocation or starvation caused by ice entrapment, are likely the major causes of bowhead mortality in the eastern Canadian Arctic since the cessation of commercial whaling (Mitchell and Reeves 1982; Nerini et al. 1984; Reeves and Mitchell 1988; NWMB 2000; Finley 2001).

9.4.3 Population Status and Protection

Northwest Hudson Bay, from Whale Cove to north of Lyon Inlet, was surveyed systematically for bowheads between 12 and 17 August 1995 (Cosens and Innes 2000). A total of 15 whales were seen in Roes Welcome Sound, Repulse Bay, Frozen Strait and Duke of York Bay, too few to determine their density using line-transect methods, so an extrapolation was made from seven observations that had inclinometer readings. The number of animals at the surface was estimated at 75 (S.E. = 27.5; 95%CI 17-133). In 1994, systematic surveys of northern Foxe Basin on 11 and 15 August saw 47 and 53 whales, respectively, and estimated the number of bowheads at the surface in the area at 256 (S.E. = 31.5) and 284 (S.E. = 48.6), respectively (Cosens et al. 1997). None of these estimates was corrected for submerged animals or for animals missed by the observers, and all have wide uncertainty. Because they were not conducted in the same year and bowheads are large, mobile animals, it may not be reasonable to combine the population estimates from northwest Hudson Bay and northern Foxe Basin to provide an overall estimate of the population. Based on aerial surveys conducted in 2002-04, preliminary estimates suggest there may be more bowheads in the eastern Canadian Arctic than was previously thought (S. Cosens, DFO, Winnipeg, pers. comm. 2004).

Based on their survey estimates and a population reconstruction by Woodby and Botkin (1993), which estimated the size of the population prior to exploitation at 575 animals, DFO (1999a) has suggested that the Hudson Bay/Foxe Basin stock may have recovered to 50% of its former size. This estimate of recovery may be premature, as the population reconstruction did not consider the unexploited portion of the population in Foxe Basin (Finley 2001). However, the collective testimony of Inuit hunters and elders from Coral Harbour, Chesterfield Inlet, and Repulse Bay suggests that bowheads were more numerous in the 1990's than in the 1950's and 1960's (NWMB 2000).

The bowhead is protected from international trade by listing on CITES Appendix 1 (Mansfield 1985) and is listed as protected by the International Whaling Commission (IWC)(DFO 1999a). It is also considered by COSEWIC to be endangered in Canada (Mansfield 1985; Campbell 1987) and is listed as endangered on Schedule 2 of the Species at Risk Act (SARA). In 1979, the Government of Canada explicitly prohibited the killing of bowhead by any person without a licence from the Minister of Fisheries and Oceans (SQR/79-644, Canada Gazette Part II, Vol. 113, Extra, Sept. 7, 1979). Harvesting activities are discussed in Chapter 14.

9.5 OTHER WHALES

A live minke whale, *Balaenoptera acutorostrata*, was sighted at Button Bay, near Churchill, on 31 July 1990 (Pattie and Webber 1992). A minke whale carcass was found on the Ontario coast of James Bay, 12 km south of Lakitusaki River in June 1986 (Abraham and Lim 1990). It may be the same animal reported stranded on the "Ontario coast of southern Hudson Bay" by R.R. Campbell (pers. comm. 1988 in Reeves and Mitchell 1989a:3). Reports of sperm whale *Physeter catodon* and northern bottlenose whale *Hyperoodon ampullatus* in Hudson Bay have not been verified, and these species were either incorrectly identified or are exceedingly rare in the region (Reeves and Mitchell 1989a).

Degerbøl and Freuchen (1935) discussed the occurrence of baleen whales in Hudson Bay with many of the whalers who had hunted there for years--none of them had ever seen any baleen whale but the bowhead in Hudson Bay.

9.6 ARCTIC FOX *Vulpes lagopus* (Linnaeus, 1758)

Arctic foxes are distributed in coastal areas and on the larger islands of Hudson and James bays (Manning 1946, 1976; JBNQNHRC 1982, 1988; Berkes and Freeman 1986) and sometimes venture onto the sea ice in pursuit of food (Degerbøl and Freuchen 1935; Forsyth 1985). On the ice they follow polar bear to scavenge at their kills (Smith and Stirling 1975; Stirling and Archibald 1977), and dig into the nearshore snow lairs of ringed seal to prey on the seal pups (Smith 1976).

Arctic foxes also scavenge along the coasts in summer, eating stranded fish and marine mammals, ground-nesting birds, small mammals, and marine invertebrates (Sutton and Hamilton 1932; Forsyth 1985). Their mobility is remarkable. A white fox tagged on 8 August 1974 at Banks Island (74°14'N, 119°55'W) was recaptured about 1500 km away on 15 April 1975 near Repulse Bay (66°27'N, 84°24'W) (T. Strong, unpubl. data).

Fox trapping was an important aspect of the fur trade in Hudson Bay and James Bay and is still important to the regional economy (Degerbøl and Freuchen 1935; Schwartz 1976; Welland 1976; JBNQNHRC 1982, 1988; Gamble 1984, 1987a+b, 1988; OMNR 1985; Berkes and Freeman 1986). Inuit trappers harvest most of the Arctic fox taken in this region while Cree, who also harvest the species, trap far more coloured foxes.

9.7 POLAR BEAR *Ursus maritimus* Phipps, 1774

Polar bears have a circumpolar Arctic distribution with the most southerly populations occurring in James Bay and southern Hudson Bay (Stirling and Ramsay 1986). These large white bears are properly referred to as marine mammals because they spend much of the year on the sea ice (Urquhart and Schweinsburg 1984). Unlike most other bears they remain active in the winter.

The range of polar bear bears in Canada has been divided into 14 populations based on the bear's seasonal site fidelity to relatively local areas, natural obstacles, traditional knowledge, and management considerations (Figure 9-6) (Taylor and Lee 1995; Lunn et al. 1998, 2002a). Bears from 3 of these populations: Western Hudson Bay (WH), Southern Hudson Bay (SH), and Foxe Basin (FB) inhabit the Hudson Bay marine ecosystem. They move largely within the boundaries of their respective polar bear management zones. Tagged bears travel widely within these zones, but few travel between zones (Jonkel et al. 1976; Stirling et al. 1977; Vandal 1987; Vandal and Adams 1988, 1989; Taylor and Lee 1995). There is some mixing of the populations on the sea ice during the winter and spring. Genetically, bears from the three populations are more similar to one another than to bears in other areas but the degree of interbreeding between populations is unknown (Paetkau et al. 1999). Juvenile and subadult bears may be more likely to undertake long distance movements than adults (Stirling and Ramsay 1986). It is not known whether these movements are permanent emigrations.

9.7.1 Distribution and Movements

The most important factor affecting the seasonal distribution and movement of polar bears is the seasonal variation in sea ice conditions. The annual ice melt generally forces bears in Hudson Bay and James bay ashore from mid-July through late August, when they are at their maximum yearly weight from feeding on fat newly-weaned seals (Jonkel et al. 1976; Stirling et al. 1977; Stirling and Ramsay 1986; McDonald et al. 1997; Stirling et al. 1999; Stirling et al. 2004). They seem to come ashore in the same areas and show long-term site fidelity (Derocher and Stirling 1990b; Kolenosky et al. 1992; Stirling et al. 2004).

Over 80% of the Western Hudson Bay population is marked and there are extensive records on this population from mark-recapture studies and the return of tags from bears killed by Inuit hunters (Lunn et al. 2002a). In the fall there is a gradual movement of bears from this population along the south coast of Hudson Bay northward to the region north of Cape Churchill (Urquart and Schweinsburg 1984). There are notable congregations on the Fox Islands off Watson Point and the small islands near Cape Churchill where they gather to

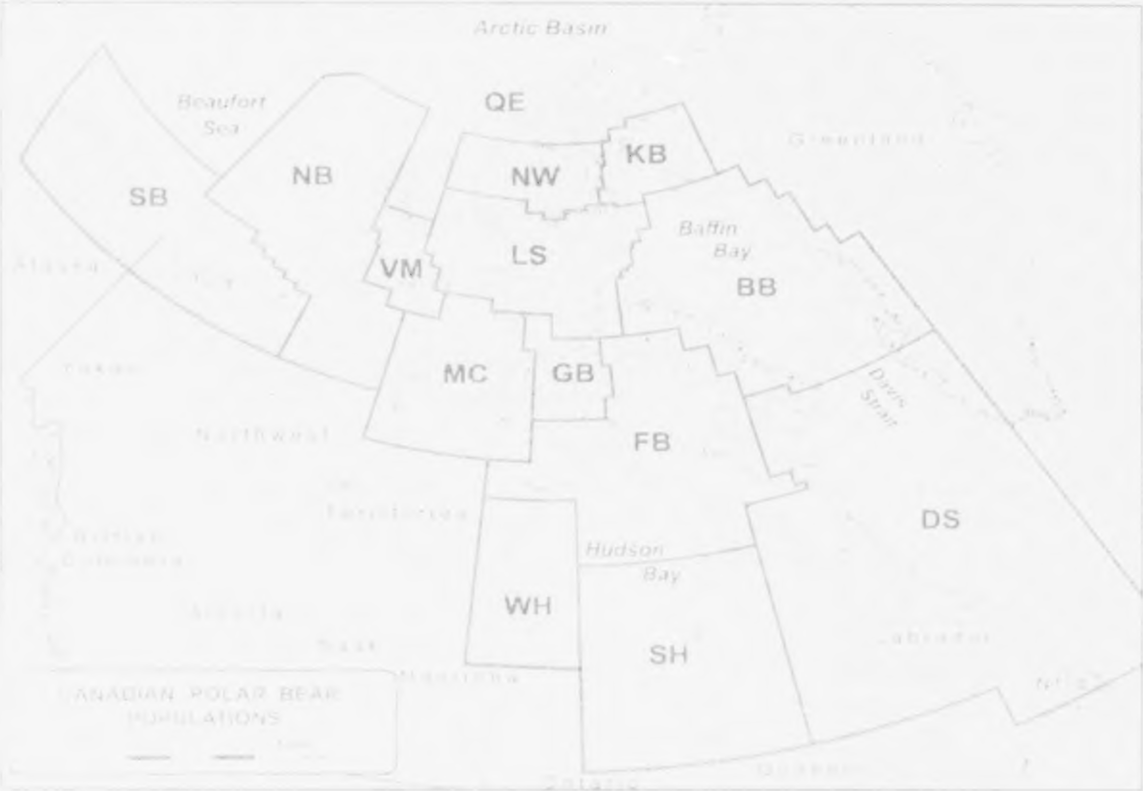

Figure 9-6. **Management boundaries for Canadian polar bear populations as of 31 December 2000 (modified from Lunn et al. 1998). BB=Baffin Bay, DS=Davis Strait, FB=Foxe Basin, GB=Gulf of Boothia, KB=Kane Basin, LS=Lancaster Sound, MC=M'Clintock Channel, NB=Northern Beaufort Sea, NW=Norwegian Bay, QE=Queen Elizabeth Islands, SB=Southern Beaufort Sea, SH=Southern Hudson Bay, VM=Viscount Melville Sound, WH=Western Hudson Bay.**

await the formation of new sea ice in November (see also Figure 5-5)(Stirling et al. 1977; Latour 1981; Derocher and Stirling 1990a,b). As soon as the ice conditions are suitable all but the pregnant females vacate their summer retreats and move offshore to resume hunting seals (Figure 9-7; Urquhart and Schweinsburg 1984). They remain on the ice throughout the winter, often hunting along leads and near the edges of land-fast ice where seals are most accessible (Jonkel et al. 1976). Variations in the annual pattern of leads and landfast ice strongly influence the distribution of bears throughout the winter. Some bears tagged in the Churchill region move northward along the Keewatin coast as far as Chesterfield Inlet (Stirling and Ramsay 1986; Stirling et al. 1999) and to Southampton Island, Ivujivik, and Inukjuak (Stirling et al. 1977). The movements of 41 adult female bears tagged at Churchill between 1991 and 1998, suggest that bears may concentrate in the area between Cape Churchill and Arviat (Figure 9-8; Derocher and Stirling 1990b; Stirling et al. 1999).

When the other bears move onto the ice in November the pregnant females remain on land to dig maternity dens in deep snowdrifts or in the earth (Stirling et al. 1977; Lynch 1993). The main maternity denning area for the population is south of Churchill in Wapusk National Park (Ramsay and Stirling 1990). Tree growth anomalies around and above den sites indicate that bears in Western Hudson Bay have shown site fidelity to maternity denning habitat south of Churchill for at least several hundred years (Scott and Stirling 2002). Some dens have been used for up to 29 years.

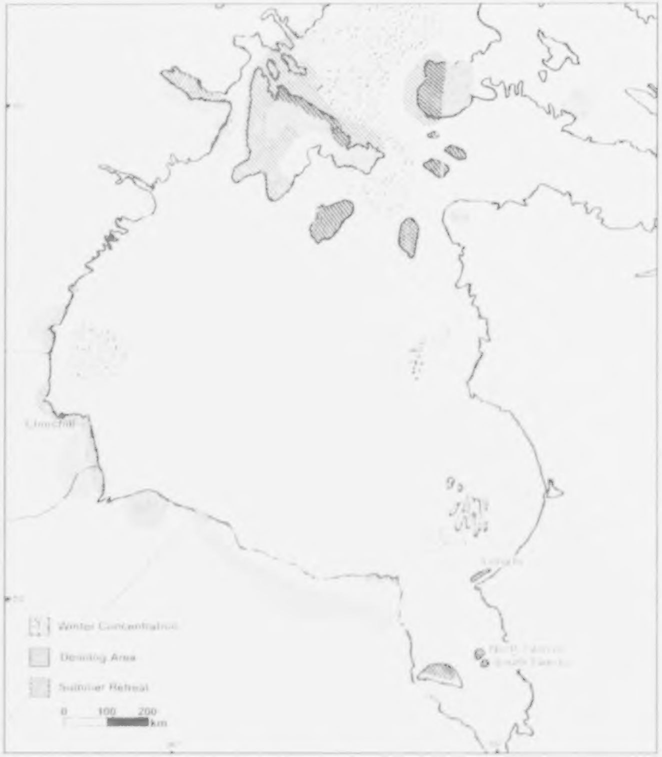

Figure 9-7. Denning habitats, summer retreats, and winter concentration areas of polar bears in the Hudson Bay and James Bay areas. Composite based on Jonkel et al. 1976; Urquhart and Schweinsberg 1984; Kolenosky and Prevett 1983; OMNR 1985; Lynch 1993; McDonald et al. 1997.

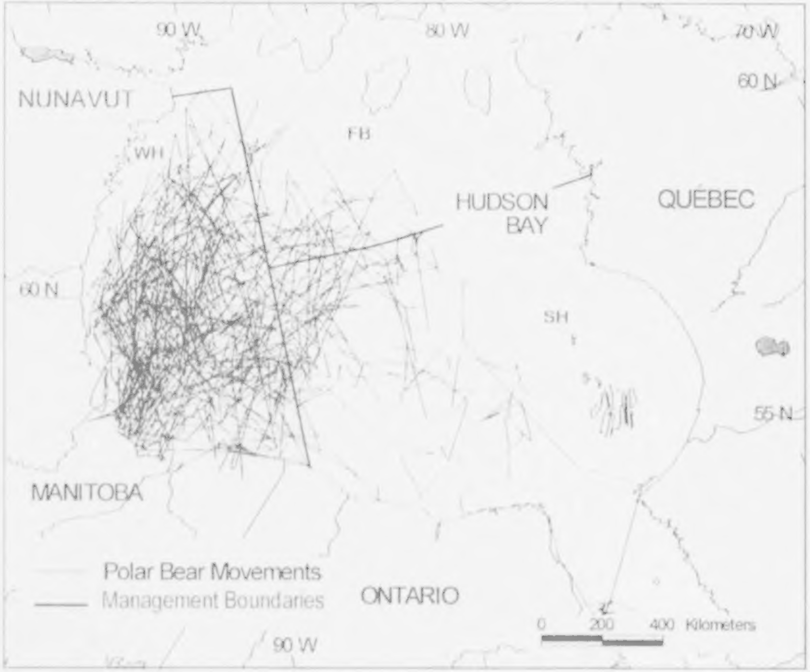

Figure 9-8. Movements of 41 adult female polar bears tagged at Churchill through a total of 46 bear years, between 1991 and 1998 (modified from Stirling et al. 1999:298). Management boundaries for the Western Hudson Bay (WH) and Southern Hudson Bay (SH) populations, and part of the Foxe Basin (FB) population are shown.

In late July and August, after the ice melts and the bears come ashore, the adult males tend to congregate on coastal capes and headlands, presumably to take advantage of the cooling onshore winds, while the family groups tend to move inland near the denning areas (Figure 9-7 and Figure 9-8; Stirling et al. 1977; Lunn and Stirling 1985; Derocher and Stirling 1990a,b; McDonald et al. 1997; Stirling et al. 2004). The daily movements of bears are less on land than on the ice (Derocher and Stirling 1990b). Radio-tracking collars are difficult to attach to male polar bears, so the seasonal movement patterns of female bears are better known. However, studies in the Beaufort Sea suggest that the distances moved by different age and sex classes of bears are similar during April through September (Armstrup et al. 2001).

Bears from the Southern Hudson Bay population (SH) spend their summers on the small islands in central and northern James Bay, on northern Akimiski Island, Long Island (Jonkel et al. 1976; McDonald et al. 1997), the outlying Belcher Islands, Twin Islands (Urquhart and Schweinsburg 1984; McDonald et al. 1997), and along the Ontario coast between Hook Point in James Bay and the Manitoba Border (Kolenosky and Prevett 1983; OMNR 1985). Akimiski Island is possibly the most southerly regular summering location used by polar bears in the world (Prevett and Kolenosky 1982). Between 1967 and 1980, late summer and fall counts found from 6 to 20 bears on the island, including females with cubs. Polar bears are rarely seen on the islands or mainland coast of southern James Bay (Jonkel et al. 1976; McDonald et al. 1997). Some animals may summer on islands adjacent to the Quebec coast.

Their seasonal pattern of onshore-offshore movements is similar to that of the Western Hudson Bay population, but the Southern Hudson Bay population appears to keep mainly to the James Bay-Hudson Bay Arc area (Jonkel et al. 1976; Kolenosky et al. 1992). Bears tagged near Cape Henrietta Maria have been recaptured north of the Belcher Islands, in northern James Bay, and to the west along the northern coast of Ontario. The area north of the Belcher islands is an extremely attractive habitat for male bears during the December to March period (Kolenosky et al. 1992).

Maternity denning areas have been confirmed southwest of Cape Henrietta Maria, on the Twin Islands, and on Akimiski Island (Doutt 1967; Jonkel et al. 1976; Stirling et al. 1977). The latter is the most southerly occurrence of reproducing polar bears in the world (Kolenosky and Prevett 1983). Maternity denning areas are suspected on the southwestern Belcher Islands, Nastapoka Island, and the Quebec mainland southeast of Cape Jones. In southern Hudson Bay and James Bay the physiological requirement of a female for a den may precede the development of suitable snow drifts in which a maternity den can be dug (Stirling and Ramsay 1986). Many bears dig earth dens initally and create snow dens similar to those in other areas of the Arctic later in the winter by burrowing into the overlying snowdrifts. They may leave the earth dens because of the need for adequate air exchange.

Coats and Mansel islands are important summer retreats for some bears from the Foxe Basin (FB) population that winter on the ice south of Southampton Island (Stirling et al. 1977; Kraft 1980; Crête et al. 1991; Gaston and Ouellet 1997). The coast of Wager Bay and the west and northeast coasts of Southampton Island are also important summer retreats for this population (Donaldson and Heard 1981; Furnell 1981). Denning is known or suspected near the south coast of Wager Bay, along the northeast coast of Southampton Island, on Mansel and Coats islands, and in northwest Quebec (Urqhart and Schweinsburg 1984). In winter, bears north of Southampton Island frequent the landfast ice along the southern half of Melville Peninsula. Polar bears move to and fro between eastern Southampton and northern Mansel islands and the northeastern coast of Labrador (Stirling and Killian 1980).

9.7.2 Biology

Polar bears live between 20 and 25 years (DeMaster and Stirling 1981). Adult male bears weigh 300 to 800 kg and are 200 to 250 cm in length from nose to tail; females are smaller, 150 to 300 kg and 180 to 200 cm.

Bears from the Southern Hudson Bay population are among the largest known (Kolenosky et al. 1989). During the period of ice cover the polar bears eat mostly ringed and bearded seals. Indeed, these seals make up an average of 96% of the diet of the Western Hudson Bay bears sampled (Iverson in Calvert et al. 2002). As top-level carnivores, they are susceptible to the accumulation of contaminants from their diet and vulnerable to changes in the availability of seals (see also Chapter 16). Bears using James Bay and Hudson Bay may be particularly vulnerable to the effects of changes in the duration and quality of the ice cover (Stirling and Derocher 1993; Stirling et al. 1999) (see also Chapter 17)

Polar bears in Hudson Bay and James Bay face a longer open water season and warmer summer than their counterparts in the High Arctic. This means that they must conserve their energy in summer to avoid starvation or overheating. Indeed, they spend most of their summer resting (Jonkel et al. 1976; Knudsen 1978). In 1969-70, bears on North Twin Island spent 86.8% of their time resting, 3.2% feeding, and the remainder travelling (Knudsen 1978). Their summer-autumn diet consisted primarily of geese (*Branta canadensis*) and crowberries (*Empetrum nigrum*). While their fat reserves will carry them through the summer (Lunn and Stirling 1985), polar bears will also eat a variety of small game, tundra berries and grasses, carrion, marine kelp and shellfish, stranded whales, garbage, and even members of their own species (Degerbøl and Freuchen 1935; Johnston 1961; Russell 1975; Jonkel et al. 1976; Miller and Wooldridge 1983; Lunn and Stenhouse 1985; Smith and Sjare 1990; Derocher et al. 1993; Smith and Hill 1996; Hobson and Sterling 1997; McDonald et al. 1997; Dyck and Daley 2002). Some bears in Wager Bay are able to catch seals during the open water season but this behaviour may be uncommon (Furnell and Oolooyuk 1980). Bears may occasionally kill walruses. The bears lose weight steadily from the time they come ashore until freeze-up in early November when they return to the sea ice to hunt (Stirling and Ramsey 1986).

Despite protracted periods away from the seals they depend upon for food, polar bears in Hudson Bay maintain a similar mean litter size to other bear populations (Derocher 1999) and reproduce more frequently (Ramsay and Stirling 1982; Kolenosky et al. 1992). The mean litter size for bears in Southern Hudson Bay is 2.04 (n = 161) and for bears in Western Hudson Bay is 1.84 (n = 274) (Derocher 1999). Females emerge with their cubs in late February to early April and return to the sea ice to feed (Jonkel et al. 1976; McDonald et al. 1997). While most polar bears wean their cubs after 2.5 years and have a 3-year breeding cycle, 40% of those in Hudson Bay wean their cubs after only 1.5 years and have a 2-year breeding cycle (Ramsay and Stirling 1982, 1986; see also Kolenosky et al. 1992). The litter size of females varies with age, increasing from maturity until 14 years of age and then decreasing (Derocher and Stirling 1994).

The higher reproductive rates in the Western Hudson Bay population have been associated with higher growth rates, but the reasons for the higher growth rates are unknown (Derocher and Stirling 1998). Female bears from this population breed for the first time between 3 and 5 years of age, and maintain high pregnancy rates from 5 to 20 years of age (Derocher et al. 1992). The average age at first breeding for female bears in western Hudson Bay is 4.1 years, by which time they have reached 97% of their asymptotic length, whereas females in other populations take between 4.5 and 5.5 years to attain the same proportion (Derocher and Stirling 1998). Breeding occurs in late March through May, but implantation of the fertilized egg may be delayed until between mid-September and mid-October; cubs are likely born from mid-November to mid-December (Derocher et al. 1992). Because female distributions on the ice are unpredictable males do not establish territories during the spring breeding season (Ramsay and Stirling 1986).

The use of earth dens by polar bears on the islands in James Bay and along the Manitoba and Ontario coasts of Hudson Bay is unique (Doutt 1967). The bears use two main types of summer dens, shallow depressions or pits and shallow burrows or dens (Doutt 1967; Jonkel et al. 1976). Pregnant females use most summer dens, although adult males occupy them occasionally in late summer and fall prior to freeze-up. The reasons for summer and fall use of earth dens are not fully understood. However, they are often dug down to permafrost, which keeps them cool and may help the bears avoid overheating, and they greatly reduce exposure to insects (Stirling and Ramsay 1986). The bears, especially pregnant females, are extremely fat when they come ashore so that they may overheat easily in the relatively warm summer weather.

Hunting and aggressive interactions with other polar bears are likely the main causes of mortality among polar bears, although starvation and ice-related mortalities may also be significant—particularly among cubs (Urquart and Schweinsburg 1984; Derocher and Stirling 1996; Dyck and Daley 2002). Cub mortality is high between emergence in the spring and the following autumn, 0.99 cubs•litter^{-1} over the 25-week period (Derocher and Stirling 1996). Females that lose their litters will adopt orphaned cubs (Atkinson et al. 1996; Lunn et al. 2000).

These large predators are an important tourist attraction in Churchill, where tours are conducted to view them in fall before they return to the ice. Their seasonal presence is also an important aspect of Ontario's Polar Bear Provincial Park (OMNR 1980), and of the Churchill Wildlife Management Area (Teillet 1988).

9.7.3 Population Status and Protection

The International Agreement on the Conservation of Polar Bears and their Habitat, which was signed in Oslo, Norway in 1973, forms the action plan for polar bear management (Derocher et al. 1998). The IUCN/SSC Polar Bear Specialist Group (PBSG), which consists of research scientists from Canada, Denmark, Norway, USA, and the former USSR developed it. This group meets every 3-4 years to discuss and coordinate matters pertaining to the research and management of polar bears throughout their range (e.g., Derocher et al. 1998; Lunn et al. 2002b). The polar bear is listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This designation is used for species that are not necessarily threatened with extinction but may become so unless trade in specimens is controlled. Consequently, there are international export restrictions on polar bear products. A federal permit is required if a bearskin is to be exported from the Province or Territory where it was killed.

In Canada, the polar bear is designated as a species of "Special Concern (formerly vulnerable)" by COSEWIC (Lunn et al. 2002a). This status was last examined and confirmed in November 2002. Species of special concern have characteristics that make them particularly sensitive to human activities or natural events that could lead to endangerment. Polar bears are listed as Special Concern under the Species at Risk Act (SARA), pending public consultation for addition to Schedule 1 (http://www.speciesatrisk.gc.ca). In January 1999, the Committee on the Status of Species at Risk in Ontario (COSSARO) listed the polar bear as 'Vulnerable".

Manitoba has legislated that the polar bear is a protected species (Lunn et al. 2002a; Scott and Stirling 2002). Preferred denning habitat of the Western Hudson Bay population is now contained largely within Wapusk National Park and the Cape Churchill Wildife Management Area. These WMAs have management plans under development that will control access to maternity denning areas and be beneficial for the survival of this population.

Recent estimates of the sizes, and assessments of the status, of the three polar bear populations found in Hudson Bay and James Bay are summarized in Table 9-2. Lunn et al. (1997) estimated the size of the Western Hudson Bay population in autumn 1995 at 1200 ± 250 animals using a mark-recapture study. The hunt sex ratio of 2 males: 1 female has resulted in a population composition that is 58% female and 42% male (Derocher et al. 1997). Southern Hudson Bay population, based on the resighting frequency (20%) of marked bears during late summer surveys, has been estimated at between 965 and 1095 animals, based on survey data from ca. 1990-96 (Calvert et al. 2002; see also Kolenosky et al. 1992). The current estimate of 2300 (SE = 350) bears in the Foxe Basin population was developed in 1996 from a mark-recapture program based on tetracycline biomarkers (Derocher et al. 1998).

Table 9-2. **Current status of Hudson Bay polar bear populations (modified from Lunn et al. 2002a).**

			5-year average (95-96 to 99-00)		
Population	**Estimate**	**Reliability[1]**	**Kill**	**% female**	**Sustainable harvest[2]**
Foxe Basin (FB)	2300	good	89.9	35.7	96.6
Southern Hudson Bay (SH)	1000	fair	45.4	36.2	41.4
Western Hudson Bay (WH)	1200	good	49.2	34.7	51.9

[1] Good = minimum capture bias, acceptable precision; fair = capture bias, precision uncertain.

2 Sustainable harvest is based on the populaiton estimate (N) for the area, estimated rates of birth and death, and the harvest sex ratio (Taylor et al. 1987): Sustainable harvest = (N x 0.015) / proportion of harvest that was female. The proportion of the harvest that was female is the greater of the actual value or 0.33.

Current harvests from the Western Hudson Bay and Southern Hudson Bay populations are believed to be sustainable (Lunn et al. 2002a). Aerial survey counts conducted annually from 1963 to 1996 show an increasing trend in the abundance of bears along the Ontario coast (Stirling et al. 2004). Similar surveys found bear abundance along the Manitoba coast to be increasing from 1963 to ca.1971, and stable from then until 1997. Past harvests reduced the Foxe Basin Population from about 3000 in the early 1970s to about 2300 (SE = 350) in 1996. The Nunavut harvest quotas have been revised to enable slow recovery of the population and co-management discussions with Quebec are ongoing.

Inuit observed an increase in the number of bears in southeast Hudson Bay between 1960 and 1990 (McDonald et al. 1997). They have also observed that polar bears throughout Hudson Bay show less fear of humans and dogs than in the past, and that those in the west and northwest are becoming increasingly aggressive and more dependent on foraging at dump-sites, camp sites, and meat caches.

9.8 ATLANTIC WALRUS *Odobenus rosmarus rosmarus*, Linnaeus, 1758

The walrus, called *aivik* in Inuktitut, is a large gregarious pinniped that is identifiable by its long canine teeth or tusks. It has a discontinuous Arctic and Subarctic distribution with distinct Atlantic and Pacific subspecies (Reeves 1978; Brenton 1979; Fay 1981, 1985). Some of the most southerly populations of Atlantic walrus are now found in southeast Hudson Bay and James Bay. Walruses are more common and abundant in northwest Hudson Bay, Hudson Strait and Foxe Basin (Richard and Campbell 1988; Mansfield and St. Aubin 1991).

Four distinct stocks of Atlantic walrus have been identified on the basis of distribution, genetic and lead isotope data in Canadian waters (Richard and Campbell 1988; Outridge and Stewart 1999; Stewart 2002; Outridge et al. 2003). Two of these, the South and East Hudson Bay Stock and the Hudson Bay-Davis Strait Stock, inhabit the Hudson Bay marine ecosystem (Figure 9-9). The former is distributed from the Ottawa Islands southward into western James Bay; the latter from Arviat north and east through Hudson Strait to Clyde River on the east coast of Baffin Island. These stocks may once have been contiguous and both may consist of sub-units that mix little or not at all. Within the South and East Hudson Bay Stock, the relationship between walruses in the Sleeper and Belcher archipelagos with those at Cape Henrietta Maria and inside James Bay is unknown. The Hudson Bay/Davis Strait Stock may consist of separate sub-stocks that inhabit northern Hudson Bay, Hudson Strait, and Davis Strait. Inuit have observed differences in body size and tusk length that are consistent with these separations, and further suggest that Chesterfield Inlet and Repulse Bay may not share the same walruses (Fleming and Newton 2003).

9.8.1 Distribution and Movements

In the absence of humans, Altantic walrus populations likely require large areas of shallow water (80 m or less) with bottom substrates that support a productive bivalve community, the reliable presence of open water over these feeding areas, and suitable ice or land nearby upon which to haul out (Davis et al. 1980). They are very

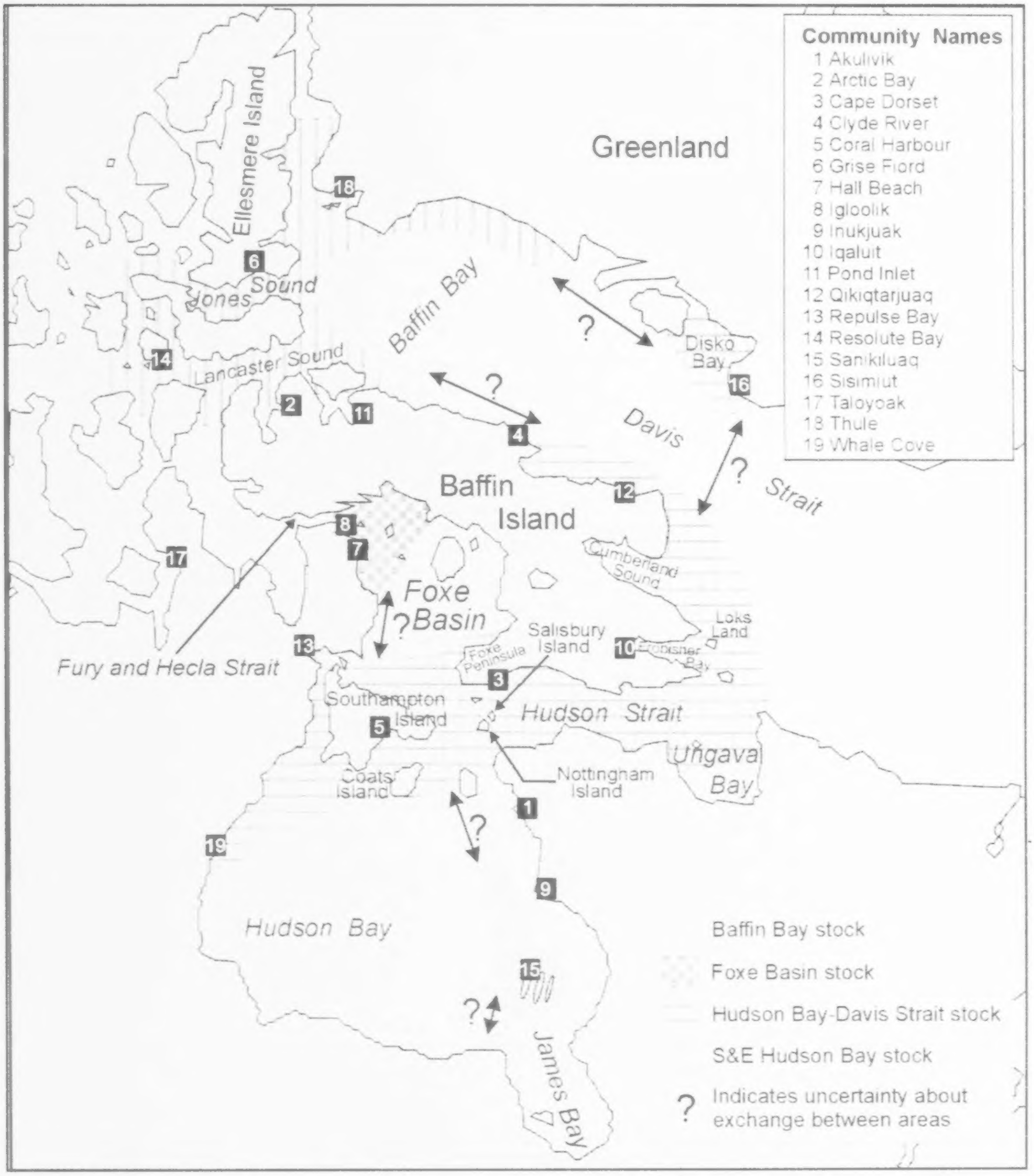

Figure 9-9. **Map of the range and distribution of Atlantic walrus stocks in eastern Canadian waters (from DFO 2000).**

gregarious and for most of the year are associated with moving pack-ice. In Hudson and James bays the scarcity of ice in summer and fall forces them to haul out on land where they tend to congregate in a few predictable locations (*uglit* or *ubliqvik* = resting place on land) (Mansfield 1973). Females with calves tend to be situated on the seaward side of the herd where protection from polar bear is greatest (Miller 1982; Miller and Boness 1983). *Uglit* are often situated on low, rocky shores with steep or shelving subtidal zones where the walruses have easy access to the water for feeding and quick escape (Mansfield 1959; Miller and Boness 1983). They generally move to more sheltered areas when there are strong onshore winds and heavy seas (Mansfield 1959).

Inuit have contributed most knowledge of walruses in eastern Hudson Bay (e.g., Freeman 1964; Schwartz 1976; Reeves 1995a; Fleming and Newton 2003). In the northeast, walruses remain in the Ivujivik area year-round (Fleming and Newton 2003). *Akulik* and *Pilik* islands, which do not appear on maps, are important sites for these animals. In the early 1990s, Ivujivik hunters would go to *Akulik* when they did not see walruses elsewhere in winter. Walruses also winter in polynya kept open by strong currents around Nottingham Island and Salisbury islands, in Hudson Strait. They are seldom present in the Akulivik area in summer, but are seen there in the fall moving northward towards Hudson Strait (Fleming and Newton 2003). A single animal was harvested at Smith Island on the Quebec coast in 1989 (Olpinski 1990).

In southeast Hudson Bay, walruses were found, sometimes abundantly, in the Belcher, King George, and Sleeper islands (Flaherty 1918; Twomey 1939; May 1942; Manning 1946; Freeman 1964; Schwartz 1976). The species has not been common in recent years in the Belchers or along the east coast, and Inuit generally travel to the Sleepers Islands to hunt them in the fall. In 1993, however, walruses were re-occupying uglit in the North Belcher Islands and Inuit believed that local walrus population might be recovering (Z. Novalinga, Sanikiluaq Environmental Committee and P. Kattuk, Mayor of Sanikiluaq, pers. comm. 1993). There is a small population of walruses that summers on the Sleeper Islands (Loughrey 1959; Manning 1976; Olpinski 1990; Fleming and Newton 2003). They are on the floe ice in early summer (June and early July) and move ashore as the pack dissipates. Walruses are also present at the open floe edge west of the Sleeper Islands in winter (P. Kattuk, Mayor of Sanikiluaq and Z. Novalinga, Sanikiluaq Environmental Committee, pers. comm. 1993).

Walruses were once widely distributed in James Bay. In the east, they occurred south to the Paint Islands (Low 1906). They have not been seen near Chisasibi in recent years (Fleming and Newton 2003), but geographical names suggest that they may once have hauled out at "Walrus Point" and "Pte. du Morse" nearby. In the Wemindji area, at *Wiipichuutukuwiih*, walrus were once numerous and posed a hazard to paddlers. In 1992, willows covered the old depressions dug by walruses in the island's shoreline. Cree harvested walruses in the Wemindji-Waskaganish area until at least 1934. In the west, walruses occurred south to Attawapiskat (Fleming and Newton 2003). They were seen in the early 1960's on ice flows between Lakitusaki River (Lake River) and Bear Island (Johnson 1961), and in the 1970's at Ekwan Point (Fleming and Newton 2003). Residents of Attawapiskat noticed fewer walruses in their area in the early 1990's but report that they are present on the mainland between Akimiski Island and Ekwan River after spring breakup. They attribute this decrease to changes in the coastline resulting from postglacial uplift (Fleming and Newton 2003).

Walruses are present along the south coast of Hudson Bay west of James Bay. Shoals near Cape Henrietta Maria are an important haulout site for walruses between July and October (Clarke in Loughrey 1959; Johnson 1961; Abraham in Richard and Campbell 1988; C. Chenier, OMNR, Cochrane ON, pers. comm. 2003). In 1993, participants in the Hudson Bay Programme's Traditional Ecological Knowledge and Management Systems (TEKMS) study reported that there were lots of walruses in the Winisk (Peawanuck) area and that walruses had been seen in July in the Fort Severn area (Fleming and Newton 2003).

In western Hudson Bay, walruses have occurred south to Churchill and become increasingly numerous moving northward. They are rare at Churchill, where six were seen off the coast near Cape Churchill in October 1954 (Johnson in Loughrey 1959). They are seldom seen near Whale Cove but were numerous at islands near the community from 1942 to 1945 (Fleming and Newton 2003). Small groups of walruses are sometimes seen at the floe edge south to Whale Cove (Gamble 1988; Fleming and Newton 2003; H.E. Welch, DFO, Winnipeg, pers. comm. 1991). In 1993, participants in the TEKMS study said that walruses were more numerous in the Chesterfield Inlet area in the early 1990's than in the past (Fleming and Newton 2003). Walruses are absent near the community in summer, but do winter in the Chesterfield Inlet-Roes Welcome Sound area and are found on the other side of the inlet in the spring (Fleming and Newton 2003; H.E. Welch, DFO, Winnipeg, pers. comm. 1991).

They occur in Wager Bay when ice is minimal and Inuit indicate that they prefer areas with strong current. Walruses are common in the Repulse Bay area (Brice-Bennett 1976; Fleming and Newton 2003). They are seen less often when ice concentration remains high during the summer. The presence of walruses also depends on the strength of the current, which varies each summer. When the current is stronger walruses are sometimes only 40 miles away from Repulse Bay in the fall. They are sometimes seen at the floe edge in winter.

A relatively large walrus population summers immediately north of the study area in the Coats Island-Bencas Island-Evans Strait-Southampton Island area (Mansfield 1955, 1958; Loughrey 1959; Welland 1976; Orr and Rebizant 1987; Mansfield and St. Aubin 1991; P. Richard, DFO, Winnipeg, pers. comm. 2003). Walruses overwinter near the south coast of Southampton Island and between Nottingham and Salisbury islands (Orr and Rebizant 1987).

While walruses can travel long distances by swimming or by riding ice floes, their seasonal movements in Hudson Bay are poorly known. Inuit from Akulivik and Ivujivik have observed walruses moving northward from Hudson Bay into Hudson Strait in the fall (Figure 9-10; Reeves 1995a; Fleming and Newton 2003). However, there is no evidence for a concerted movement of walruses into or out of southeastern Hudson Bay. Instead, there are local seasonal movements between the rocky sites where they haul out during the ice-free period and

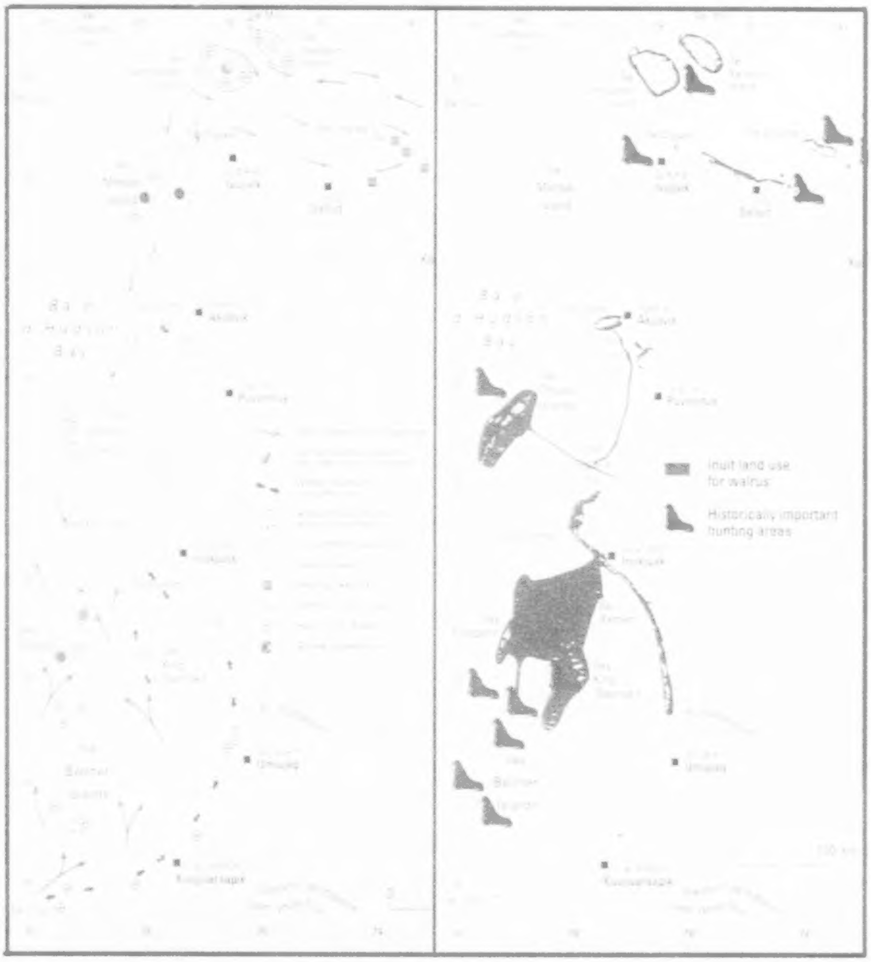
Akulivik
Akulivik
Inuit land use for walrus
Historically important hunting areas

Figure 9-10. **Inuit ecological knowledge (left) and regional land use and historical distribution (right) of walruses in south and east Hudson Bay (adapted from Reeves 1995a).**

overwintering areas (Freeman 1964). In both the Belcher and Sleeper archipelagos, walruses stay at the floe edge during winter and move into the islands shortly after break up (Fleming and Newton 2003). Hunters report a seasonal movement of walruses around Coats, Walrus, and Southampton islands and between Foxe Peninsula and Nottingham and Salisbury islands (Orr and Rebizant 1987). They also describe a seasonal shoreward movement of walruses as ice conditions permit in the Repulse Bay and Coral Harbour areas in the fall (September) (Fleming and Newton 2003). On Akpatuqjuaq and Akpatuuraajuk islands (Mansel and Coats islands) walruses migrate to their uglit in springtime and disperse in the fall.

9.8.2 Biology

The biology of the walrus in the Hudson Bay ecosystem is poorly documented. Elsewhere, most walruses inhabit areas where water is less than 80 m to 100 m deep and they can dive to the bottom to feed (Vibe 1950; Fay 1985). Most feeding is done at depths of 10 to 80 m (Vibe 1950; Mansfiled 1958; Born et al. 2003) and some dives can take 24 minutes (Gjertz et al. 2001). Walruses are grazers rather than diggers, locating their benthic prey with their tusks and vibrissae and then rooting into the mud with their snout (Loughrey 1959; Fay 1981). Pelecypods, particularly *Mya truncata*, are their main prey, but many other invertebrates, fishes, the occasional seal, and even birds are also eaten (Degerbøl and Freuchen 1935; Vibe 1950; Mansfield 1958; Loughrey 1959; Fisher 1989; Reeves 1995a; Fleming and Newton 2003). In winter, walruses in the Repulse Bay area try to get close to the land for access to feeding areas (Fleming and Newton 2003).

Their low reproductive rate makes walruses vulnerable to over-harvesting and environmental perturbations. Walruses are polygynous and while males are gregarious out of the breeding season they compete intensely for the females during the mating season (Fay 1981; Sjare and Stirling 1996; Sjare et al. 2003). Mating occurs on the ice in mid-winter and as a result reproductive behavior is not well known (Fay 1985). Females mature between the ages of 5 and 10 years and give birth once every three years on average (Mansfield 1958; Born 1990; Garlich-Miller and Stewart 1999). Young are born in May or June, after a gestation period of 15 or 16 months, and suckle for up to 2 years (Fay 1985; Fisher and Stewart 1997). Calves moult in their first summer and during each summer thereafter (Mansfield 1958).

Male Atlantic walruses average 305 cm in length and have long, straight, stout ivory tusks; females average 250 cm in length and have smaller curved tusks (Mansfield 1958). Walruses may live 35 year and mature males can grow to over 1150 kg.

9.8.3 Population Status and Protection

As the number of whales in Hudson Bay dwindled towards the end of the last century whalers turned their efforts to harvesting other species, including large numbers of walruses (Low 1906; Degerbøl and Freuchen 1935). The large-scale commercial harvest and sport hunting of walruses was banned in Canada by an order in the Privy Council (P.C. 1036) in 1928 (see Mansfield 1973). There are no estimates of the level of exploitation, but the walrus population in the Canadian Eastern Arctic is apparently much reduced (Manning 1946; Schwartz 1976; Richard and Campbell 1988).

A comprehensive survey of walrus populations in Hudson Bay and James Bay has not been conducted. In the spring of 1955, a herd estimated at over 1000 animals was seen hauled out on the sandspit at Cape Henrietta Maria (Clarke in Loughrey 1959) and in September 1955, the captain of the Fort Severn saw a herd off the coast at Winisk (Loughrey 1959). Born et al. (1995), have questioned the accuracy of the former estimate, which was told to Clarke, and cautioned against its use in determining population trend. The Ontario Department of Natural Resources (DNR) has recorded opportunistic observations of walruses at shoals off the mouth of the "Brant River" since 1957 (C. Chenier, DNR, Cochrane, ON, pers. comm. 2003). Walruses have been seen on the shoals between July 20th and October 18th. The number of animals varies widely and no trend is apparent in the population. High counts recorded by Ontario DNR have ranged from 310 on 5/10/78 (dd/mm/yy; J.P. Prevett), to 204 on 9/9/83 (K.F. Abraham), to 330 on 8/9/86 (K.F. Abraham), to about 221 in August 1999 (C. Chenier).

In the late 1930's, Twomey and Herrick (1942) saw and hunted a herd they estimated at over 400 animals in the northern Sleeper Islands. Since then only smaller herds have been reported form the region. On 4 August 1971, Manning (1976) saw 75 walruses near the south end of the Sleeper Islands, and the next day saw 25 off the west coast of Kidney Island, largest of the Sleeper Islands. A herd of about 30 animals was seen at the Sleepers in October 1996; nine of these animals were harvested (Brooke 1997). In the summer of 1993, a herd of about 30 animals was seen in the Belchers directly north of Sanikiluaq during an aerial survey (J. Desrosier, Quebec, QC, pers. comm. 2003). Hunters report that there are fewer walruses near the community and on neighbouring islands now, than in the past (DFO 2000).

In the early 1990's walrus were reportedly numerous along the Ontario coast of Hudson Bay west to the Winisk (Peawanuck) area, and have been seen in July in near Fort Severn (Fleming and Newton 2003). This coastline may provide a refuge for the population, since Cree hunters do not have a well-developed tradition of hunting walruses and take few animals (Johnston 1961).

Richard and Campbell (1988) and Born et al. (1995) estimated the size of this population at 410+ and 500? animals, respectively. Both of these estimates were tentative and based on a few sightings in a wide geographical area over a long period. Taking the largest direct counts of the past decade or so, as did Richard and Campbell (1988), yields an updated estimate of 270+ animals (Stewart 2004b). While this suggests a decline, data are too few to assess whether one has occurred.

Aerial survey counts of walruses in the northern Coats Island, Walrus Island and southeast Southampton Island area of northern Hudson Bay were conducted in July or August of 1954 (Loughrey 1959), 1961 (Mansfield 1962), 1976-77 (Mansfield and St. Aubin 1991) and 1988-90 (Richard 1993b). They produced maximum counts, respectively, of 2900 (Loughrey 1959: 80), 2650 (Mansfield 1959: 46), 2370 (Mansfield and St. Aubin 1991: 97), and 1376 (Richard 1993b: 7) walruses. These numbers are conservative, as they are not based on systematic surveys of the entire area and were not corrected for animals missed by the observers. While they suggest a declining trend, care must be taken in interpreting these data given differences in survey methods and ice coverage, and wide fluctuations in the numbers of animals hauled out at any particular time. Richard's (1993b) counts in 1988-90, for example, were above the average of the daily counts in 1976 and 1977. On Coats Island, Gaston and Ouelett (1997) counted about 600 animals at Cape Pembroke on 7 August 1992 and about 500 at Cape Prefontaine on 31 July 1995. Hunters from Coral Harbour have reported an increase in the number of walruses near their community over the past 10 years (DFO 2000).

Walruses were more common and numerous along the west coast of Hudson Bay between Arviat and Chesterfield Inlet in the past (Loughrey 1959; Born et al. 1995). They are now found mostly in the area north of Chesterfield Inlet. They have abandoned various *uglit* in western Hudson Bay but hauled out in small numbers in summer at Bibby Island (61°53'N, 93°05'W), Term Point (62°08'N, 92°28'W), Little Walrus Island (in Mistake Bay), Sentry Island (61°10'N, 93°51'W), Wag Island (63°23'N, 90°38'W), Marble Island (62°41'N, 91°08'W), and Fairway Island (63°15'N, 90°33') as recently as the 1950's (Low 1906; Degerbøl and Freuchen 1935; Loughrey 1959; Reeves 1978; Born et al. 1995; DFO 2000; Fleming and Newton 2003) (Figure 9-11). Small groups of walruses are sometimes seen at the floe edge south to Whale Cove (Gamble 1988; Fleming and Newton 2003). They are uncommon in the area but were numerous at islands near the community from 1942 to 1945 (Fleming and Newton 2003). Inuit report that walruses were more numerous in the Chesterfield Inlet area in the early 1990's than in the past (Fleming and Newton 2003). No counts are available for this region.

Inuit around Hudson Bay have linked the disappearance of walruses from traditional harvesting areas variously to poor and wasteful harvesting techniques, to harvest rates that are too low to stimulate an increase in the reproductive rate, and to natural shifts in the species' distribution (Fleming and Newton 2003). In the past,

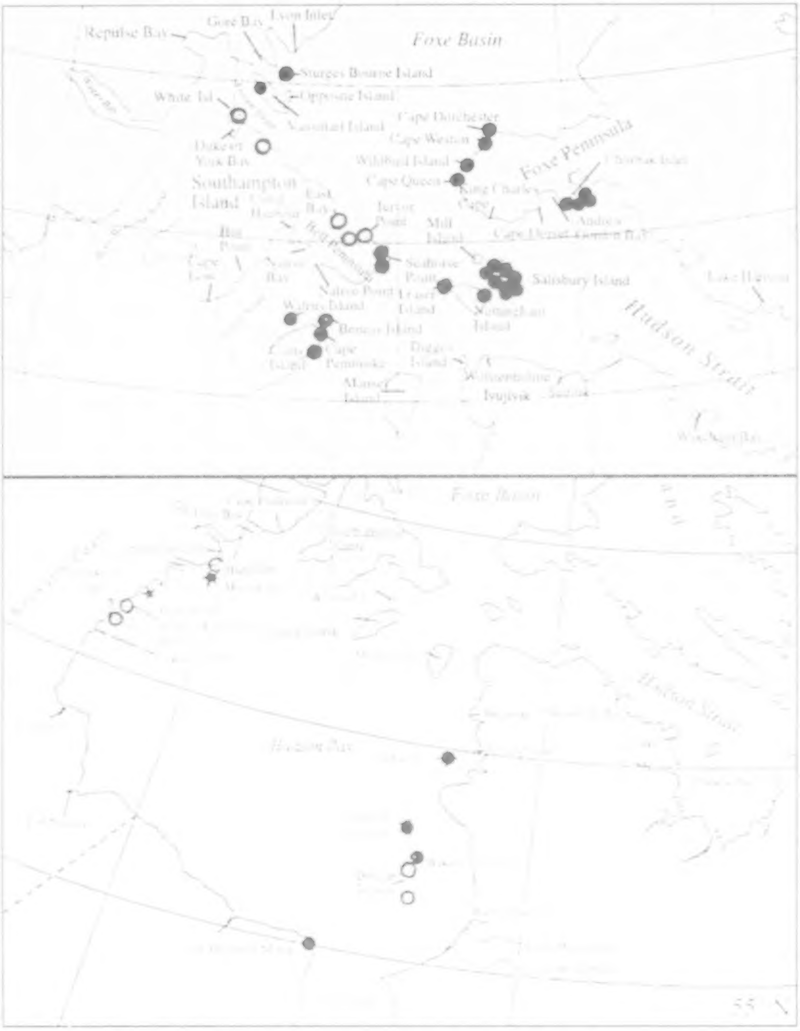

Figure 9-11. **Locations of terrestrial haulouts (uglit) in northern Hudson Bay and Hudson Strait (top) and in southern, eastern, and northwestern Hudson Bay (bottom; adapted from Born et al. 1995). Legend: Black dots = haulouts still known or beleved to be used by walruses. Open circle = historical haulouts; present status unknown. Stars = Abandoned haulouts.**

unregulated harvesting from motorboats disturbed animals at haulouts in the Belchers, Sleepers, and along the west coast of Hudson Bay, possibly with high mortality. Walrus remains were also discarded at the haulouts and, together with sinking losses, tainted both the haulouts and feeding grounds causing the walruses to leave the area. Inuit recognize the sensitivity of walruses to habitat disturbance and the mortality of other walruses in their traditional knowledge.

> *"When I was growing up, I remember, my father and the others used to say never try to kill a walrus where you think it will sink right into the feeding areas, or never cut up the walrus where they usually bask or rest. The elders used to say never to leave the guts near the islands where they bask. If you do that the walrus will move away from there."(Zach Novalinga, Sanikiluaq).*

In contrast, eastern Hudson Bay Inuit have suggested that population declines may be the result of too few walruses being killed for food to keep the reproductive rate high (Fleming and Newton 2003).

The disappearance of walruses from an area may not indicate a decline in the population but rather movements in search of richer feeding grounds or better haulouts (Fleming and Newton 2003). Likewise, their occupation of sites where they were seldom seen in the past, such as *ullikuluk* near Coral Harbour in 1993, does not necessarily indicate an increase in population. Changes in the coastline have made some island haulouts in the Winisk area part of the mainland coast, reducing their use by walruses. Declining use of habitat in the Attawapiskat area has also been attributed to coastal changes but increased boat traffic may also be a contributing factor.

COSEWIC has not assigned a status to Atlantic walrus populations in Hudson Bay and James Bay (Richard and Campbell 1988) but a status update is ongoing (Stewart 2004b). Careful population management involving native harvesters is required for conservation of the existing populations (see also Chapter 14). The Atlantic walrus is listed on Appendix III of the Convention on International Trade in Endangered Species (CITES).

9.9 BEARDED SEAL *Erignathus barbatus* (Erxleben, 1777)

The bearded or squareflipper seal is a large, solitary seal with a continuous circumpolar distribution in Arctic and Subarctic waters (McLaren 1958a; Mansfield 1967a; Burns 1981; Cleator 1996). The species is distributed widely in Hudson Bay and James Bay, where it is resident year-round. Individuals can be distinguished from other Arctic seals by the absence of color patterns on the body, presence of long white whiskers, square foreflippers, and habit of swimming at the surface with their back out of the water. They are much less abundant than the ringed seal, and may be limited by dependance on areas of high benthic productivity for food (Mansfield et al. 1975).

9.9.1 Distribution and Movements

Bearded seals prefer areas of moving pack ice and open water where the water depth is less than 150 to 200 m, but they sometimes maintain breathing holes in landfast ice or occupy deeper areas (McLaren 1958a; Mansfield 1967a; Smith 1981; Cleator 1996). They are relatively sedentary but may move between coastal and offshore areas in response to ice changing conditions. They typically occur alone or in small groups and their distribution is patchy and has relatively low density. Aggregations of bearded seals are most likely during the winter months prior to breakup and during early summer when the availability of ice pans for haulout is limited. During the open water period they will enter estuaries and haul out on land, sometimes in the company of harbour seals (Remnant 1997; Bernhardt 1999a, 2000a).

9.9.2 Biology

Bearded seals generally grow to an average of 2.1 to 2.4 m in length and can weight over 350 kg (Burns 1981; Smith 1981; Cleator 1996). Smith (1981) found that females mature between age 4+ and 7 years and that most reproduce annually, while McLaren (1958a) found that they mature at age 6+ years and breed biennially. Breeding likely occurs between mid-April and late May, and implantation is delayed about two months (Smith 1981). The single pups are born on the ice in April or May and abandoned after 12 to 18 days of nursing (Mansfield 1967a; Burns 1981; Smith 1981). They can swim immediately after being born and begin to feed independently immediately after weaning. These seals can live about 31 years (Benjaminson 1973), and a 25 year-old female was taken at the Belchers (Smith 1981).

The most important food items of bearded seals in the Belcher Islands are decapod crustaceans, pelecypod molluscs and fish, mainly Arctic cod (*Boreogadus saida*) (Smith 1981). Prey selection may be based on prey availability, so their diet may vary within a relatively small area and over a short period (Antonelis et al. 1993). Their long whiskers, or vibrissae, are sensitive to touch and are used to locate benthic prey. Hunting and predation by polar bears are likely the main causes of mortality among bearded seals, which are stalked when they haul out on the ice to nap (Sutton and Hamilton 1932; Stirling and Archibald 1977). Bearded seals are uncommon in areas frequented by walruses, suggesting that there is either inter-specific competition for benthic prey or predation by walruses (Cleator and Stirling 1990).

The bearded seal is one of the least visible of the Canadian Arctic phocid seals, but is the most actively vocal, with a varied underwater repertoire (Smith 1981; Cleator et al. 1989; Terhune 1999). The frequency-modulated sounds are often heard where no bearded seals are observed (Smith 1981).

9.9.3 Population Status and Protection

McLaren (1962) estimated the bearded seal population of the Belcher Islands at 13,050 animals. This estimate was not based on systematic survey data. Smith (1975) and Simard et al. (1980) saw few bearded seals during their late May surveys of southeast Hudson Bay and James Bay for ringed seal. Aerial systematic strip transect surveys have been conducted for these species in western Hudson Bay. The areas surveyed in 7-14 June 1994 and 1-4 June 1995 extended north from the Nelson River estuary to Rankin Inlet and offshore to 90° W longitude (Lunn et al. 1997). In 1994, the bearded seal population was estimated at 12,290 (SE = 2520) with a density of 0.122 seals·km^2 of ice; in 1995, it was estimated at 1,980 (SE = 560) with a density of 0.024 seals·km^2 of ice. The widely different estimates may be related to differences in the timing of the surveys. Additional survey work was conducted in 1997, 1999, and 2000 (Calvert et al. 2002) but the results are not yet available (N. CWS, Edmonton, pers. comm. 2004).

The species has not been assigned a status under the CITES or by COSEWIC (Cleator 1996).

9.10 HARBOUR SEAL *Phoca vitulina* Linnaeus, 1758

The harbour seal is distributed along the entire length of Canada's east and west coasts and is widely distributed in the eastern Canadian Arctic and Subarctic (Mansfield 1967a+b; Bigg 1981). Small, local populations occur sporadically around the coasts of Hudson and James Bay, and there are resident populations in some fresh water drainages of the Hudson Bay watershed. The adults tend to be sedentary, and inhabit areas that have open water year-round. They tend to be solitary in the water but form small groups when hauled out on rocky shores.

9.10.1 Distribution and Movements

There are small resident populations of harbour seals along the coasts of Hudson Bay and James Bay in isolated localities where tidal rips, swift current, and river outflows keep small areas ice free throughout the winter--many of these areas are estuaries (Doutt 1942; Mansfield 1967a+b; Welland 1976). Some harbour seals also inhabit the floe edge in winter (Welland 1976). Seals that winter in fresh water in the Lacs des Loups Marins area take advantage of open water but may also use under-ice shoreline shelters caused by lowered water levels (Smith and Horonowitsch 1987). These areas may provide important resting sites for seals and protect them from low temperatures and predators.

Harbour seals like fresh water and have also been found well inland in summer in Ennedai Lake (Mansfield 1967b) and the Thleiwaza River system in Nunavut (Beck et al. 1970). Seals, probably harbour seal, also occur in Manitoba's Seal River system inland to Stony Lake and are common in Shethanei Lake (G. Dodds, Parks Planning Consultant, Winnipeg, pers. comm. 1991). Baker (1989) observed harbour seals in the Nelson River estuary from 5 July to 6 October when observations ended. They are also common in the Churchill River, from the estuary to the upper end of Long Island, 55 km upstream from the river mouth (Remnant 1997). They are present in fresh water immediately upstream of the water level enhancement weir from mid-May through at least mid-October (Remnant 1997; Bernhardt 1999, 2000). There are resident harbour seal populations in the Upper and Lower Seal Lakes on the Nastapoka River (Doutt 1942; Power and Gregoire 1978) and in Kasegalik Lake on Flaherty Island in the Belchers (Freeman 1964; Manning 1976).

There is no evidence for migrations of harbour seals from the Atlantic into the Hudson Bay, or for migrations of animals from the Seal Lakes in Quebec to or from the sea (Mansfield 1967b). Seals apparently occupy Lower Seal Lake year-round, wintering near rapids at the mouth of the outlet (Doutt 1954), and have modified the lake's fish community through their predations (Power and Gregoire 1978). Mansfield (1967b) suggests that watersheds may have been a favoured summer resort for wandering young harbour seals, a few of which may have remained in the Upper and Lower Seal Lakes. With the advent of the high-powered rifle the coastal harbour seals may have been heavily exploited, resulting in the virtual isolation of the lake seals.

In the Belchers, harbour seals do ascend the Kasegalik River in summer (Freeman 1964). Their favorite haulouts include small rocky outcrops in Kasegalik Lake, islets in the Kasegalik River, and some deep inlets on the southwest coast. "Kasegalik" means the place of harbour seals (Manning 1946).

Based on their jaw measurements and dark pelage, Doutt (1942) suggested that the seals in Upper and Lower Seal Lakes represent a distinct subspecies, *P. v. mellonae*, which had developed since the lakes were isolated by post-glacial emergence. Mansfield (1967b) believed this to be unlikely, since there is overlap in the jaw measurements with the other subspecies *P. v. concolor*, dark pelage is common among Arctic harbour seals, and there are a number of routes by which the seals might have entered the lakes in recent years. However, molecular genetic differences suggest that the two subspecies may be reproductively isolated (Smith and Lavigne 1994).

9.10.2 Biology

Adult harbour seals of both sexes average about 150 cm in length and 90 kg in weight (Mansfield 1967a). They are bluish-grey on the back and belly with a faint pattern of white markings. In the Arctic, the females mature at age 2 to 5 years and breed annually, giving birth to a single pup, on land, in late June or July (Bigg 1969, 1981). Twomey and Herrick (1942) found afterbirth on a rock at Kasegalik Lake on Flaherty Island. The presence of current year pups at the Churchill River estuary in the fall of 1996, suggests that pupping also occurs in the Churchill area (Remnant 1997). Pups are precocious in their swimming habits since they must often take to the water before the next tide covers their birthplace (Mansfield 1967a). They are abandoned after a lactation period of 2 to 6 weeks and can live for 30 years (Bigg 1981). Young harbour seals can undertake migrations of 1,475 km (Beck 1983) and for this reason the species is also known as the ranger seals.

Little is known of the Arctic marine diet of the harbour seal, but elsewhere it preys upon a wide variety of inshore fishes, squids, and crustaceans (Bonner 1979; Bigg 1981). The species will eat lake trout and whitefish when in freshwater (Beck et al. 1970). Dodds (pers. comm.) observed seals, probably harbour seals, catching Arctic grayling in rapids on the Seal River. Eagles and foxes prey upon newborn seals, while sharks, killer whales, polar bears, and walruses prey upon the adults (Bonner 1979). Harvesting is likely one of the greatest causes of mortality among these seals (see also Chapter 14).

Blasting activities during construction of the weir across the Churchill River caused harbour seals to leave their haulouts and enter the water (Bernhardt 1999a). It did not displace them permanently from the haulouts; they would swim in the area and sometimes hauled out again within 5 minute of the blast. They appeared to habituate to the frequent airboat traffic on the river but would enter the water if a boat stopped nearby and haul out again when it left. They would approach to within 50 m of construction personnel working on the weir. Inundation of their pre-project haulout about 500 m upstream of the weir, caused the seals to relocate to another haulout in the reach of river within 1 km downstream (Bernhardt 2000a).

While little is known of harbour seals in Hudson Bay and James Bay, the University of Alberta and Canadian Wildife Service are currently studying the biology of the species in the Churchill area (W. Bernhardt, North/South Cons. Inc., Winnipeg, pers. comm. 2004).

9.10.3 Population Status and Protection

The number of harbour seals in Hudson Bay and James Bay has not been estimated. Use of the Churchill River estuary by harbour seals was studied during the summers of 1996 through 1999 to assess possible effects of the Lower Churchill River Water Level Enhancement Weir Project (Remnant 1997; Bernhardt 1999a, 2000a). In 1999, up to 21 seals, mostly harbour but some bearded, were hauled out at once; these numbers fluctuated on a daily and seasonal basis.

Estimates of the freshwater harbour seal population in the Lacs des Loups Marins area are imprecise and range from 100 to 600 animals (Smith 1996, 1997).

COSEWIC designated the Atlantic subspecies of the harbour seal *P. v. concolor* as data deficient (formerly indeterminate) in April 1999, on the basis that insufficient information was available to determine the status (Baird 2001). The Lacs des Loups Marins subspecies *P. v. mellonae* was designated special concern (formerly vulnerable) in April 1996, on the basis of its limited range and low numbers which make it vulnerable to human impact and natural catastrophic events (Smith 1997). Freshwater seals north of the 55th parallel are listed as protected species under the James Bay and Northern Quebec Agreement; however, this protection does not have the force of law (Gunn in Smith 1996).

Harbour seals are not listed under CITES, so international trade in products from the species is not monitored or regulated (Baird 2001). The IUCN has designated the species as "insufficiently known", meaning that it is "suspected but not definitely known to be endangered, vulnerable, or rare due to a lack of reliable information".

9.11 RINGED SEAL *Phoca hispida* (Schreber, 1775)

These small seals have a wide distribution in seasonally and permanently ice-covered waters of the Northern Hemisphere (Frost and Lowry 1981). The ringed seal is the most common and abundant species of seal in Hudson Bay and James Bay, where it is resident year-round (Smith 1975; Sergeant 1986).

9.11.1 Distribution and Movements

Ringed seals occur in water of virtually any depth and their distributions likely are driven primarily by food availability and ice conditions (Reeves 2001). During the winter, adult ringed seals generally occupy stable landfast ice where they maintain a number of breathing holes by abrading the ice with the claws of their fore flippers, and build subnivean lairs in which to haul out and/or pup (McLaren 1958b; Frost and Lowry 1981; Smith 1987; Smith et al. 1991). The ability to maintain holes through the ice throughout the winter enables them to occupy large areas of the Arctic that are inaccessible to other marine mammals except during the summer (Davis et al. 1980). In spring, the highest densities of breeding adults occur on stable landfast ice in areas with good snow cover, whereas non-breeders occur at the floe edge or in the moving pack ice (Smith 1975; Holst et al. 1999). Jonkel (in Smith 1975) found significant numbers of ringed seals in the very centre of Hudson Bay in March 1972.

In their breeding habitat ringed seals are strongly territorial (Smith 1987). They can often be seen in spring when they come out onto the ice beside their breathing holes to bask in the sun and moult their hair coat (Mansfield 1967a; Manning 1976). During the open water season seals of all ages are found nearshore (Frost and Lowry 1981). They tend to be solitary except during the moulting season (Stirling and Calvert 1979).

Little progress has been made in identifying stocks of ringed seals, and the patterns of movement and degree of genetic interchange between areas are not well known (Frost and Lowry 1981; Reeves 2001). While the species is generally assumed to be sedentary, individuals will move over 1300 km in a season (Smith 1987;

Teilmann et al. 1999). General mass movements have not been documented in Hudson Bay and James Bay but seasonal changes in distribution related to the presence and quality of ice are likely.

9.11.2 Biology

Adult ringed seals average 125 cm in length and 65 kg, and are identifiable by characteristic ring-shaped color patterns on their body fur (Stirling and Calvert 1979). The average lifespan is probably between 15 and 20 years (Frost and Lowry 1981) but individuals may live to age 43 years (McLaren 1958b). Females first become pregnant between the age of 4 and 7 years and generally breed annually (Frost and Lowry 1981; Holst et al. 1999). Breeding takes place in mid to late May, and implantation is delayed for about 3 months (Reeves 2001). Pups are born singly in snow lairs between late February and early April, and the nursing period is partly dependant on ice stability (Figure 9-12; Cleator 2001; Reeves 2001). Pups in subnivean birth or haul-out lairs with thin snow roofs are more vulnerable to predators than those in lairs with thick ones (Smith and Stirling 1975). In the drift ice of the Sea of Okhotsk pups only nurse for about 3 weeks (Fedoseev 1975) while in the more stable ice areas they typically nurse for 5 to 7 weeks (Frost and Lowry 1981). During the nursing period pups double in weight and shed their wooly white coats. They are abandoned at ice break-up (McLaren 1958b; Frost and Lowry 1979).

Prior to the 1990's, recruitment rates of ringed seals in western Hudson Bay appeared to be related to the timing of spring breakup, which was correlated with the North Atlantic Oscillation (Ferguson et al. 2005) (see also Section 4.1.4). Studies in 1990-2001 suggest that decreased snow depth--particularly below 32 cm, possibly influenced by the timing of spring breakup, has had a detrimental affect on ringed seal recruitment in western Hudson Bay (Ferguson et al. 2005).

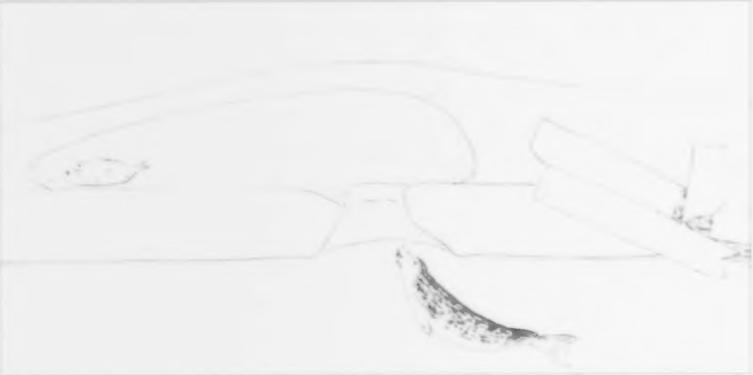

Figure 9-12. Ringed seal birth lair (from Mansfield 1968:380).

While ovulation rates among ringed seals sampled near Arviat in 1990-91 and 1991-92 were high, 100% and 83% respectively, the pregnancy rates were relatively low, 61% and 48% respectively (Holst et al. 1999). The reasons for these relatively low reproductive rates are unknown but poor feeding conditions may be a factor. Studies of the food habits of ringed seals in the Arviat area are ongoing (Calvert et al. 2002).

Ringed seals are adaptable in their feeding habits and eat a variety of pelagic, nectonic, and benthic invertebrates and fishes--particularly the amphipod *Themisto libellula* (synonym *Parathemisto libellula*), the mysid *Mysis oculata*, Arctic cod (*Boreogadus saida*), and sculpins (McLaren 1958b; Smith 1987; Weslawski et al. 1994; Cleator 2001). Unlike bearded seals they seldom eat burrowing invertebrates. In winter they take more benthic prey whereas during ice-breakup and in open water they take more pelagic prey (Weslawski et al. 1994). This may be a reflection of the seasonality of the pelagic invertebrate community. McLaren (1958b) observed a seal near Churchill diving to a depth of 26 to 28 m to feed on benthic decapods. Individuals can dive to a depth of at least 340 m (Innes in Reeves 2001:26). They can remain submerged for well over 20 minutes and dives to 250 m are not uncommon (Teilmann et al. 1999).

Polar bears are the main predators on ringed seals (Russell 1975; Stirling and Archibald 1977; Furnell and Oolooyiuk 1980; Smith 1980) but Arctic foxes are also important predators on newborn seals (Smith 1976,1987).

There is incidental predation by killer whales (Reeves and Mitchell 1988) and walruses (Vibe 1950; Mansfield 1958; Loughrey 1959). Hunting is also a major cause of mortality among ringed seals (see Chapter 14).

9.11.3 Population Status and Protection

Estimates of ringed seal populations are based mainly on aerial surveys conducted during the peak haulout and moulting period from late May to early July. Smith (1975) conducted an aerial survey of Hudson Bay between the 13th and 20th of June 1974. He saw an average of 1.48 seals·km^{-2} in the shorefast ice between Churchill and Chesterfield Inlet, 0.37 seals•km^{2} in offshore areas containing consolidated pack made up of large ice pans, and 0.11 seals·km^{-2} for other offshore areas with greater amounts of broken ice and open water. Very low population densities of seals, 0.12 seals·km^{-2} near shore and 0.21 seals·km^{-2} offshore, were observed between Winisk and Churchill. Ice in this area was apparently unstable and unsuitable for haul-out or breeding. These densities do not account for seals that were under the ice. By doubling the observed densities to account for seals that were under the ice and multiplying each by the area of that ice type in Hudson Bay, he estimated that there were 455,000 ringed seals in Hudson Bay--including Roes Welcome Sound and waters south of a line between Seahorse Point and Cape Wolstenholme but not including James Bay. McLaren's (1958b) estimate of 218,300 ringed seals in roughly the same area did not account for seals in the offshore ice.

Smith (1975) found very low densities of ringed seals, 0.12-0.24 seals·km^{-2}, during a similar aerial survey of James Bay. This survey was conducted on 26 and 27 May 1974, when ice breakup was well advanced. Rather than use these densities, which he believed would underestimate the population, Smith (1975) extrapolated densities derived for the nearshore and offshore ice types in Hudson Bay to estimate a population of 61,000 ringed seals in James Bay.

Southeast Hudson Bay provides good ringed seal habitat since it has a large area of stable landfast and offshore ice in winter (see also Figure 5-6). The area between Long Island and Petite rivière de la Baleine was surveyed for ringed seals and their breeding lairs between the 20th and 30th of May 1978 (Simard et al. 1980). This aerial systematic strip-transect survey extended 40 km offshore and encompassed an area of 10,000 km^2. The area's ringed seal population was estimated at between 14,400 and 21,400 animals. Breeding lairs were common between Grande rivière de la Baleine and Petite rivière de la Baleine. Little is known of seals in Richmond Gulf, but Richard Couture (pers. comm.) saw breeding lairs and very many ringed seals during a low helicopter flight over the gulf in April.

Aerial systematic strip transect surveys have been conducted for ringed seals in western Hudson Bay. The areas surveyed in 7-14 June 1994 and 1-4 June 1995 extended north from the Nelson River estuary to Rankin Inlet and offshore to 90° W longitude (Lunn et al. 1997). In 1994, the number of seals hauled out on the ice in this area was estimated at 38,340 (SE = 3640) with a density of 0.381 seals·km^{-2} of ice; in 1995, it was estimated at 140,880 (SE = 8100) with a density of 1.690 seals·km^{-2} of ice. The widely different estimates may be related to differences in the timing of the surveys. These estimates are likely conservative because they are based on the number of seals hauled out on the ice and were not corrected for seals that were submerged. The total population of the area may be twice as large (Sterling and Øritsland 1995). Additional survey work was conducted in 1997, 1999, and 2000 (Calvert et al. 2002) but the results are not yet available (N. Lunn, CWS, Edmonton, pers. comm. 2004).

The species has not been assigned a status under the CITES or by COSEWIC (Cleator 1996).

9.12 HARP SEAL *Phoca groenlandica* (Erxleben, 1777)

The harp seal is common in the north Atlantic and adjacent Arctic regions from about 90° east to 90° west longitude (Ronald and Healey 1981; Lavigne and Kovacs 1988). In early May, large herds of harp seals begin their northward migration from whelping and moulting grounds in the Gulf of St. Lawrence and off the southeastern coast of Labrador to summering areas in the eastern Canadian Arctic and off west Greenland (Sergeant 1965). While most continue northward into Lancaster Sound and Baffin Bay, some enter Hudson Strait and move westward into Foxe Basin and Hudson Bay (Mansfield 1967a). They are common in Hudson Strait before the shore ice leaves in spring, rare in summer, and common again in autumn after the shore ice forms (Low 1906).

Migrants are present in Hudson Bay from ice break-up in early June until just before freeze-up in early October (Sutton and Hamilton 1932; Mansfield 1968; Gamble 1984, 1987a+b, 1988). They occur south to Arviat in the west (Gamble 1984, 1987a+b, 1988) and Chisassibi in the east (Sergeant 1986), and are present during the open water season in the Belchers (Freeman 1964, 1967; Mansfield 1967a, 1970). Manning (1946) saw groups of six harp seals outside Inukjuak in mid-late July and at Gilmour Island, in the Ottawa Islands, in late August. Freeman (1964) reported that harp seals might pass offshore the Belcher Islands in the fall. In 1975, Cree from Chisasibi killed a small number of juvenile (young-of-the-year) seals, probably at Cape Jones (Sergeant 1976, 1986). The species is less common in Hudson Bay and James Bay than ringed or bearded seal, but may have been more numerous and widespread in the past (Bell 1884). As recently as the early 1970's harp seal were rare along the Kivalliq coast south of Rankin Inlet (R.E.A. Stewart, DFO, Winnipeg, pers. comm.). With the Atlantic population on the increase (Roff and Bowen 1986) the species may be re-occupying its former range. Hunters at Coral Harbour reported harvesting harp seals in January and February of 1984 (Gamble 1987a), suggesting that some may overwinter in the region.

These seals can grow to about 163 cm in length and 135 kg in weight (Mansfield 1967a), and live 30 years (Sergeant 1976). They have silver pelage with dark spots that fade with age to eventually give way to a dark saddle along the flanks and over the back, accompanied by a black face (Mansfield 1967a). Males are generally more boldly marked and may be darker all over at about 4 years, including being completely black (Stewart 1983). Females mature between 4 and 7 years of age (Sergeant 1976) and bear one pup annually thereafter (King 1964). Adults eat a variety of pelagic fish and pelagic and benthic Crustacea, and smaller amounts of benthic fish (Sergeant 1973). Their major cause of mortality is likely hunting by man (Davis et al. 1980) (see Chapter 14).

The number of harp seals using Hudson Bay and James Bay is unknown. The species does not have a CITES or COSEWIC designation, so there is no monitoring or restriction in the international trade in products from the species. Marine Mammal Export permits are, however, required from DFO to export seal parts from Nunavut.

9.13 HOODED SEAL *Cystophora cristata* (Erxleben, 1777)

The hooded seal is a rare summer visitor to Hudson Bay and perhaps James Bay. A single male was reported at the mouth of the Kaskattama River, Manitoba, in the fall of 1955 (Mansfield 1968), and Captain Ferris of the HBC ship Fort Garry shot what was probably a hooded seal on the ice of Cape Henrietta Maria sometime in the 1940's or 50's (Johnson 1961).

Hooded seals are generally found in Arctic and Subarctic regions of the North Atlantic (Reeves and Ling 1981; Kovacs and Lavigne 1986). They tend to occur farther offshore and occupy deeper water than harp seal, and to prefer thick drifting ice to fast ice (Sergeant 1974; Lavigne and Kovacs 1988). Adult males have an average standard length of 2.5 m and body mass of about 300 kg. They inflate their proboscis (hood) and extrude their nasal septum during threat displays. Females are smaller at 2.2 m and 160 kg and only have tiny hoods.

Hooded seals migrate northward from their wintering areas in the North Atlantic into Foxe Basin in July and return southward in September (Koski 1980; T. Qillaq, Clyde River, pers. comm. 1985). Presumably those in Hudson Bay and James Bay follow a similar schedule.

The species was examined by COSEWIC in April 1986 and designated "Not at Risk". It has not been assigned a status designation under CITES.

9.14 SUMMARY

The extreme southerly presence of Arctic marine mammals is characteristic of the Hudson Bay marine ecosystem. Walruses, ringed seals, bearded seals, and harbour seals are resident in the waters year-round, while Arctic foxes and polar bears frequent coastal areas in summer and ice habitats during other seasons. The quality, extent and duration of the sea ice cover are vitally important determinants of their seasonal distributions, movements, and reproductive success. Heavy pack ice and landfast ice limit which species can survive and where they winter and reproduce. Some walruses remain at the ice edge or in the pack ice over the winter, while others move northeast into Hudson Strait. The duration of ice cover determines how long polar bears can hunt seals and whether seals can successfully reproduce and moult. While polar bears and Arctic foxes use these ice environments as a platform upon which to travel and hunt seals, the other species must maintain access to the surface to breathe.

The resident seal species move on or offshore to access seasonally preferred ice habitats. Ringed seals, and occasional bearded seals, are the only animals that can maintain breathing holes through the mature landfast ice. They use it as a stable platform upon which to haul out, build birth lairs, pup, and moult. They also inhabit consolidated and open pack ice, as do bearded seals and walruses. Harbour seals frequent areas where currents maintain open water year-round, typically in freshwater or estuarine rapids or small coastal polynyas or at the ice edge. Their reliance on ice makes ringed and bearded seals, polar bears, and walruses vulnerable to changes in the ice environment of Hudson Bay and James Bay (see also Chapter 5 and Chapter 17).

Harp and hooded seals and five species of whales are seasonal visitors that move into the region as ice conditions permit in the spring. The beluga, narwhal and bowhead are migratory Arctic whales that winter mostly in the pack ice of Hudson or Davis straits. They follow ice leads or penetrate the pack as it dissipates and are typically the first to arrive in spring and last to leave in the fall. Belugas are the only whales found commonly in James Bay and southeastern Hudson Bay, while narwhals and bowheads remain mostly in northwestern Hudson Bay. Harp and hooded seals that winter in the North Atlantic arrive a bit later in the season, once most of the pack ice has dissipated, and leave earlier in the fall. Killer whales live at all latitudes and migrate into Hudson Bay in summer; the minke whale is a temperate-water species and rare summer visitor. There are also reports of sperm whales and northern bottlenose whales in Hudson Bay but their occurrence has not been confirmed and at best they are rare.

The timing of these seasonal movements can vary by a month or so from year to year, depending upon ice conditions. Most movement data, polar bears excepted, comes from observations of species' arrival and departure times at harvesting locations. Since most harvesting is done near the coast, offshore movements are virtually unknown. The seasonal movements and population dynamics of polar bears are better known. Long-term radio tracking studies of polar bears, particularly in western Hudson Bay, have identified distinct Southern Hudson Bay, Western Hudson Bay, and Foxe Basin populations. Bears from each of these areas show fidelity to maternity denning and summering areas but mix on the ice of central Hudson Bay in winter.

Polar bears in Hudson Bay and James Bay face a longer open water season and warmer summer than their counterparts in the High Arctic. They must conserve their energy to avoid starvation or overheating, and lose weight steadily from the time they come ashore until freeze-up in early November when they return to the sea ice to hunt. Despite the protracted periods of starvation these bears maintain a similar mean litter size to other polar bear populations and reproduce more frequently. The mean litter size for bears in Southern Hudson Bay is 2.04 (n = 161) and for bears in Western Hudson Bay is 1.84 (n = 274). Females emerge with their cubs in late February to mid-March and return to the sea ice to feed. While most polar bears wean their cubs after 2.5 years and have a 3-year breeding cycle, 40% of those in Hudson Bay wean their cubs after only 1.5 years and have a 2-year breeding cycle. The higher reproductive rates in the Western Hudson Bay population have been associated with higher growth rates, but the reasons for the higher growth rates are unknown.

The whale species and the walrus all have relatively low reproductive rates, producing a single calf about every three years on average over their reproductive life. The rate of calf mortality is relatively low as the females feed and protect their young for the first several years of their lives. The vital rates of narwhals are uncertain because there is no accurate method to determine their ages. The seal species have a greater reproductive potential since they can reproduce annually. However, this potential is not always met; the actual pregnancy rate among ringed seals in western Hudson Bay can be 48-61%. The rate of mortality among seal pups is high, as they are eaten by polar bears and Arctic foxes, and weaned and abandoned after a period of weeks or a few months.

The whales, most seals, and perhaps walruses can dive to the bottom to feed throughout James Bay and most, if not all, of Hudson Bay. However, little is known of these species' diets or energetics in the region. As top-level carnivores, polar bears are particularly susceptible to the accumulation of contaminants from their diet and vulnerable to changes in the availability of seals (see also Chapter 16). Arctic foxes scavenge polar bear kills and prey upon ringed seal pups.

Various populations of walruses and whales have been identified for management purposes in Hudson Bay and James Bay on the basis of seasonal distribution, genetics, contaminant loads or other factors. Some of these populations are shared with communities on Hudson Strait, Foxe Basin, Davis Strait, or the Atlantic coast. The genetic interchange among populations, within and outside the region, is unknown. Two putative walrus populations have been identified in the region, one in South and East Hudson Bay and the other in Hudson Bay-Davis Strait. Narwhals from the Hudson Bay population and bowheads from the Hudson Bay-Foxe Basin population summer in northwest Hudson Bay, and may mix with other populations on their wintering grounds in Davis Strait. The largest summering concentration of belugas in the world occurs in the Nelson River estuary area, and there are smaller concentrations at the estuaries of the Seal, Churchill, Winisk, Severn, and Nastapoka rivers. Use of these estuaries by belugas may be related to neonate survival and/or moulting. Belugas in eastern and Western Hudson Bay are treated as separate populations.

Estimates of marine mammal populations in the region, based on systematic aerial surveys or counts at walrus haulouts, likely are conservative as they have not been corrected for animals submerged beyond view, and all but the polar bears can hold their breath for over 20 minutes (Table 9-1). The number of belugas summering in James Bay may have increased fourfold between 1985 and 2001, while numbers in eastern Hudson Bay declined by almost half. The increase in James Bay cannot be explained by reproduction alone, other contributing factors may include survey timing and immigration from Hudson Bay. The latter has important implications for population management and argues the need to improve understanding of the relationships between animals in these areas. In eastern Hudson Bay, the decline in numbers of belugas, offshore and at estuaries was accompanied by a decrease in the mean age of the catch. DFO has cautioned that continuing current levels of harvesting (>140 EHB beluga killed in 2001 by communities in Hudson Bay and Hudson Strait) could cause this population to disappear within 10 to 15 years.

There is little scientific or traditional information to indicate large changes in the region's other marine mammal populations over the past 20-50 years, but scientific survey information is very limited. The bowhead population remains severely depleted by commercial whaling that ended a century ago, and the historical range of walruses in James Bay and western Hudson Bay is much reduced. Hunting and disturbances caused by motorboats and snowmobiles may be causing narwhals and walruses to avoid areas near the communities.

The Committee on the Status of Endangered Wildife in Canada (COSEWIC) has designated bowhead and the eastern Hudson Bay belugas "**Endangered**"; the Lac des Loups Marins subspecies of harbour seal, polar bear, narwhal, western Hudson Bay beluga population as "**Special Concern** (formerly Vulnerable)"; the hooded seal as "**Not at Risk**"; and the Atlantic subspecies of the harbour seal as "**Data Deficient**". An update of the status of Atlantic walrus populations in Canada is ongoing. The Committee on the International Trade in Endangered Species (CITES) has listed bowhead under Appendix I, which protects them from international trade.

Belugas, narwhals and polar bears are listed under Appendix II, which is reserved for species that could be threatened with extinction if trade is not controlled and monitored, and Atlantic walrus are listed under Appendix III. A CITES export permit is required to transport products from these species across international boundaries. Marine Mammal Export permits are required from DFO to export marine mammal products from Nunavut. Harvesting levels are discussed in Chapter 14.

Table 9-3. Population estimates of marine mammals in areas of Hudson Bay and James Bay.

Species	Area	Survey dates	Population estimate[a]	Reference
Beluga	James Bay	1985	1,842[b]	Smith and Hammill 1986
		1993	3,141 (SE = 787)	Kingsley 2000
		2001	7,901 (SE = 1744)	Gosselin et al. 2002
	eastern Hudson Bay	1985	2,089[b]	Smith and Hammill 1986
		1993	1,032 (SE = 421)	Kingsley 2000
		2001	1,194 (SE = 507)	Gosselin et al. 2002
	southwest Hudson Bay (Nelson, Churchill and Seal river estuaries)	17-18 July 1987	23,000 belugas (95% CI 14,200-26,800)	Richard et al. 1990
	northwest Hudson Bay (Repulse Bay, Frozen Strait)	late July 1982-84	mean estimates of 700 (95%CI 200-3,300) to 1,000 (95%CI 621-1,627)	Richard et al. 1990
Narwhal	northwest Hudson Bay (Repulse Bay area)	July 1984	1355 (90%CI = 1000-1900)	Richard 1991
		August 2000	1780 (90%CI = 1212-2492)	Richard pers. comm. 2002
Bowhead	northwest Hudson Bay (Whale Cove to north of Lyon Inlet)	12-17 August 1995	75 (S.E. = 27.5, 95%CI 17-133)	Cosens and Innes 2000
Polar bear	western Hudson Bay (WH)	1995	1200 (95%CI = 950-1450)	Lunn et al. 1997a
	southern Hudson Bay (SH)	1996	1000 (965-1095)	Calvert et al. 2002
	Foxe Basin (FB)	ca. 1996	2300 (SE = 350)	Derocher et al. 1998
Walrus	northern Hudson Bay	26 August 1977	2370 (haulout surveys)	Mansfield and St. Aubin 1991
	Coats Island	August 1990	1376 (direct count)	Richard 1993b
	Nottingham Island	August 1990	461 (direct count)	Richard 1993b
	Cape Henrietta Maria	August 1999	221 (direct count)	C. Chenier, OMNR, Cochrane ON, pers. comm. 2003
Bearded seal	western Hudson Bay, Nelson River estuary north to Rankin Inlet and offshore to 90° W longitude	7-14 June 1994	12,290 (SE = 2520); 0.122 seals•km^{-2} of ice	Lunn et al. 1997b
Ringed seal	Hudson Bay, not including James Bay	13-20 June 1974	227,500[c]	Smith 1975
	James Bay		30,500 (extrapolated from Hudson Bay data)	Smith 1975
	western Hudson Bay, Nelson River estuary north to Rankin Inlet and offshore to 90° W longitude	1-4 June 1995	140,880 (SE = 8100); 1.690 seals•km^{-2} of ice	Lunn et al. 1997b
	southeast Hudson Bay, coastal waters between Long Point and Petite riviere de la Baleine extending 40 km offshore	20-30 May 1978	14400-21400, 1.44 to 2.14 seals•km^{-2} of ice	Simard et al. 1980

[a] = estimates were not corrected for seals in the water or whales submerged beyond view.

[b] = Data collected in 1985 did not allow a line transect analysis, so the value is the product of the strip transect estimate and the mean ratio of line/strip transect estimates for the given stratum for the two following surveys.

[c] = 1.48 seals•km^{-2} of landfast ice between Churchill and Chesterfield Inlet, 0.37 seals•km^{-2} of offshore consolidated pack ice, 0.11 seals•km^{-2} of broken ice and open water.

10.0 BIRDS

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The Hudson Bay marine ecosystem provides resources of critical importance to migratory waterfowl and shorebirds. Hudson Bay has the effect of funnelling southward migrating species of Arctic shorebirds and waterfowl into James Bay. With its rich coastal marshes, wide tidal flats, and extensive eelgrass beds, James Bay is one of the most important stopping places for migrating Arctic-breeding shorebirds and waterfowl in North America. It is matched only by the Copper River delta and Bristol Bay in Alaska and, for shorebirds, by the upper Bay of Fundy. These birds, particularly the geese and ducks, have sustained, and continue to sustain, important subsistence harvests by Inuit and Cree. These harvests are discussed is Section 14.6.

The history of ornithological research in the Hudson Bay and James Bay dates back to the 1700's. Birds were a vital food of the early explorers and traders who often kept an accurate record of their observations or collected specimens. Indeed, the endangered (or possibly extinct) Eskimo curlew, *Numenius borealis* (Forster), was first described from specimens collected at Fort Albany; the blue morph of the snow goose, sandhill crane, sora, Hudsonian godwit, red phalarope, red-necked phalarope, northern harrier, whimbrel, horned grebe, and gyrfalcon were also first described from specimens collected in the Hudson Bay region--many of them by early employees of the Hudson's Bay Company (Houston 1983). Despite the long history of research, there are a number of gaps in our knowledge of this region's bird fauna. Most studies have examined coastal areas during spring, summer and/or fall, and geographical observations of the seasonal occurrence and breeding of birds are skewed somewhat by the intensive bird watching activity at Churchill, Manitoba. We do not know to what extent birds use offshore waters, overwinter in open water areas, or even what bird species inhabit long stretches of coastline.

At least 133 species of swimming birds, shorebirds, raptors, and scavengers frequent offshore, inshore, intertidal, or salt marsh habitats of the Hudson Bay marine ecosystem (Appendix 4). Few of these species are year-round residents; most arrive about the time of ice break-up and depart before freeze-up. The area provides coastal breeding habitat for at least 102 species, including many that are primarily Arctic breeders--some of which are rarely seen in breeding condition outside the Arctic Islands. It also provides vitally important feeding, staging, and/or moulting habitats for many resident and transient species. An examination of Godfrey's (1986) Birds of Canada reveals that many small woodland birds also breed along the shores of James Bay, particularly southern James Bay, and nowhere else along Canada's Arctic coast.

Waterfowl and shorebird use of eelgrass beds and coastal wetlands, including salt marshes and tidal flats, is discussed in Sections 6.4 and 6.5. The coastal wetland habitats are protected by a number of migratory bird sanctuaries and parks. Maps and descriptions of these areas are provided in Chapter 12.

The following sections provide brief descriptions of the bird species that use the waters and shores of the Hudson Bay marine ecosystem. The text is based on Snyder (1957), Todd (1963), Godfrey (1986), Cadman et al. (1987), and Alsop (2002) and to improve its readability other references used have only been cited where they add significantly to the information. A more extensive list of references is cited in support of Appendix 4, which summarizes the regional distribution and breeding of each species, and provides scientific names.

10.1 F. GAVIIDAE: Loons

Loons are large swimming birds that are often seen on open water. They dive frequently, swim well under water, and can stay submerged for long periods in the pursuit of fish, which make up a large part of their diet. Loons are awkward on land and seldom come ashore except during nesting. They have spectacular courtship and distraction displays during the breeding season. Three loon species: red throated, Pacific, and common, breed near the coasts and are present during the open water season while a fourth, the yellow-billed loon, is a casual visitor that breeds further to the north and west (Appendix 4).

The red-throated loon is an Arctic breeding species that is common and numerous along the mainland and island coasts of Hudson Bay coast, but uncommon in James Bay. Northern migrants pass through Churchill between 10 and 15 June, sometimes in hundreds, and in some years flocks of 30 to 40 remain at the river mouth (Taverner and Sutton 1934; Jehl and Smith 1970). The migrants nest along the mainland and island coasts of Hudson Bay and James Bay, mostly north of the treeline beside small, often coastal, tundra ponds. Some of the more southerly breeding reports are from near Cape Henrietta Maria and South Twin Island, in James Bay. Adults nesting near the coast often feed at sea while immature migrants spend all summer on salt water--yearlings of the other loon species are not known to migrate to the breeding grounds. Young and adults move to the sea once the young can fly. Unlike the other species, the red throated loon can take off from land and moults in autumn--instead of winter or spring. It is also more sociable and may be observed in groups at good feeding areas or in migratory flocks. Red-throated loons are seldom seen at Churchill after mid-Sepember, but some linger later on or near Hudson Bay, since a flock of 30 was seen flying towards the Bay on 20 October 2000 (Chartier 1994 cited in MARC 2003).

The Pacific loon, formerly included with the Arctic loon, is another Arctic breeding species. Its summer range and breeding distribution in this region are similar to those of the red-throated loon, but the species may be more common in western than eastern Hudson Bay. Northern migrants appear in the Belchers and in ice leads off Churchill in mid-May, and by mid-June hundreds may be congregated near the mouth of the Churchill River (Jehl and Smith 1970; MARC 2003). An estimated 10,000 of these loons passed northward near Churchill on 8 June 1980 (MARC 2003). Breeding adults favour larger lakes than the red-throated loon, both near the coast and inland. They frequently forage in coastal salt water and tend to favour more offshore waters than the red-throated loon. Young and adults move to the sea once the young can fly and often congregate in loose flocks.

The common loon has a more southerly distribution and is less apt to feed at sea than the other species, but will fish off the edge of marine shoals. It breeds on islands or along shores of lakes or rivers, mostly south of the treeline. It is common in southeastern Hudson Bay and James Bay, but less so further north and west. The species occurs on Southampton Island, but apparently is not common on the islands in northern Hudson Bay.

Red-throated and Pacific loons generally winter off the British Columbia coast, and rarely are seen in the southern interior of Canada. The Twin Islands are some of their most southerly breeding habitat. Common loons are common throughout most of southern Canada. Cree and Inuit hunters in Quebec and Ontario harvest loons, mainly red-throated and common, for food (JBNQNHRC 1982, 1988; Berkes et al. 1992) (see Section 14.6).

10.2 F. PODICIPEDIDAE: Grebes

Grebes are "tailless" waterbirds with smaller, shorter bodies than loons and, usually, straighter necks. Like loons, they are excellent swimmers and divers with legs attached far back on the body that make them awkward on land. Unlike loons they have lobbed toes, not fully-webbed ones, and their tail feathers are vestigial. Pied-billed grebe and horned grebe breed along the southwestern coast of Hudson Bay and near Moosonee, and may forage in coastal waters. Both species are rare summer visitors to the region but are widely distributed in southern Canada.

10.3 F. PROCELLARIIDAE: Fulmars

The northern fulmar is a rare but regular visitor to southern James Bay in late fall (McRae 1992). Twenty of these seabirds were seen at Netitishi Point--between Hannah Bay and Moose Factory, in 1981; three more were seen east of Hannah Bay at East Point in 1985. It has also been observed at northern Coats Island (Gaston and Ouellet 1997).

10.4 F. HYDROBATIDAE: Storm-petrels

Storm-petrels are small birds that spend most of their lives at sea and ordinarily come ashore only to nest. Their flight is swallow-like and close to the water, following the ups and downs of the waves. Leach's storm-petrel was a casual summer visitor near Kuujjuarapik in 1982. It is commonly found along Canada's southern seacoasts.

10.5 F. PELECANIDAE: Pelicans

These large, piscivorous birds typically feed in freshwater and live well south of Hudson Bay and James Bay. However, a single American white pelican was found dead near Hannah Bay, the southernmost tip of James Bay, in late June 1944 (Lewis 1944), and a few have wandered north to the mouths of the Churchill and Nelson rivers along the Manitoba coast (MARC 2003).

10.6 F. SULIDAE: Gannets

Gannets are large, long-winged birds with massive tapered bills. They catch fish by diving headlong into the sea from a height of about 30 m (MARC 2003). An immature northern gannet was seen at Netitishi Point late in the fall of 1981--probably driven south from Hudson Strait or northern Hudson Bay by storm winds (McRae 1992), and an adult was seen at Churchill on 17 June 1989 (MARC 2003).

10.7 F. PHALACROCORACIDAE: Cormorants

These fish-eating, water birds have wettable wings that enhance their diving ability (MARC 2003). The double-crested cormorant is a summer visitor to the Manitoba coast, where it may feed in coastal waters. The species is a common breeder in southern Canada east of British Columbia. Perhaps the only cormorant colony on the Arctic coast has been reported at Way Rock, a small rocky islet off Boatswain Bay near the southern tip of James Bay (Lewis and Peters 1941; Todd 1963; see also East 1938). Birds from this colony ranged widely in search of food. The present status of this colony is unknown.

10.8 F. ARDEIDAE: Herons and Bitterns

Five Ardeid species that visit this region in summer may forage in coastal salt marshes, the American bittern; the great blue, little blue, and tricolored herons; the snowy egret; and the black-crowned night heron. The American bittern ranges north to Kuujjuarapik on the east coast of Hudson Bay and to Churchill on the west coast. It is a common breeder in marshy habitats along the Ontario coast of James Bay and also breeds on Charlton Island, along the Quebec coast north to Chisasibi, and in marshy habitats along the south coast of Hudson Bay from Cape Henrietta Maria west to Churchill. The great blue heron is often seen at the mouth of the Moose River, where breeding is suspected, and has been reported at Eastmain. A stray was observed at the murre colony on northern Coats Island in 1991 (Gaston and Ouellet 1997). The snowy egret is an accidental visitor along the Ontario coast north to the mouth of the Attawapiskat River and at Churchill. In summer, the American bittern, great blue heron, and black-crowned night heron are common and widespread in southern Canada, while the egret is a rare non-breeding wanderer throughout southern and central Canada. The black-crowned night heron and little blue heron are accidental visitors to the Manitoba coast; the latter is rare in southern Canada (MARC 2003).

10.9 F. ANATIDAE: Geese, Swans, and Ducks

At least 35 Anatid species breed along the coasts and frequent coastal marine habitats in summer, and a few overwinter (Appendix 4). Some species are colonial and can be very numerous in suitable habitats. Large areas of the Hudson Bay and James Bay coasts provide critically important habitat for migrating and moulting North American waterfowl (Curtis and Allen 1976). Waterfowl are very important to the regional economy, both for subsistence and to attract sport hunters. Their harvest is discussed further in Section 14.6.

During the breeding season most of these waterfowl frequent low-lying, sometimes hummocky, moist to wet vegetated tundra near lakes or coastal river mouths. The eiders are exceptions and often nest on low-lying rocky coasts and islands, especially where mussel beds and reefs provide feeding grounds. After the young hatch they often congregate in flocks along the coasts. Along the Ontario coast, the greatest numbers of dabbling ducks occur in fall, for all species, while divers are often most numerous in summer--numbers of the latter decline in fall largely due to the departure of the black scoter (Ross 1982).

Most of the species are also common spring and fall coastal migrants in this region and in southern Canada, but the eiders are rare inland or in southern Canada except along the east coast. The coastal marshes of James Bay provide an important food resource for geese spring and fall (Rae 1888; Wypkena and Ankney 1979; Thomas and Prevett 1982). Some waterfowl, such as tundra swan, can be seen on open water at the edge of ice floes when they first arrive while others, such as snow goose, frequent coastal river mouths and marshes during migration. While Canada and snow geese migrate northward in early to mid breakup, brant generally arrive in late May or early June when most of James Bay is open. The ducks and geese prefer areas of James Bay and Hudson Bay that are characterized by wide coastal marshes with an emergent zone of *Puccinella phryganodes* and a variety of vegetational associations leading to freshwater inland fens (Martini et al. 1980b). The considerable impacts these birds have on vegetation and sediments are discussed in the Section 6.5. Species such as northern pintail and greater scaup frequent coastal marine waters outside of the breeding season. Others, including the common and king eider, also frequent coastal marine waters during the breeding season. Common eiders are sometimes found well offshore.

10.9.1 Geese

Five species of geese visit James Bay and Hudson Bay: the Canada goose, snow goose, brant, Ross' goose, and greater white-fronted goose (Appendix 4).

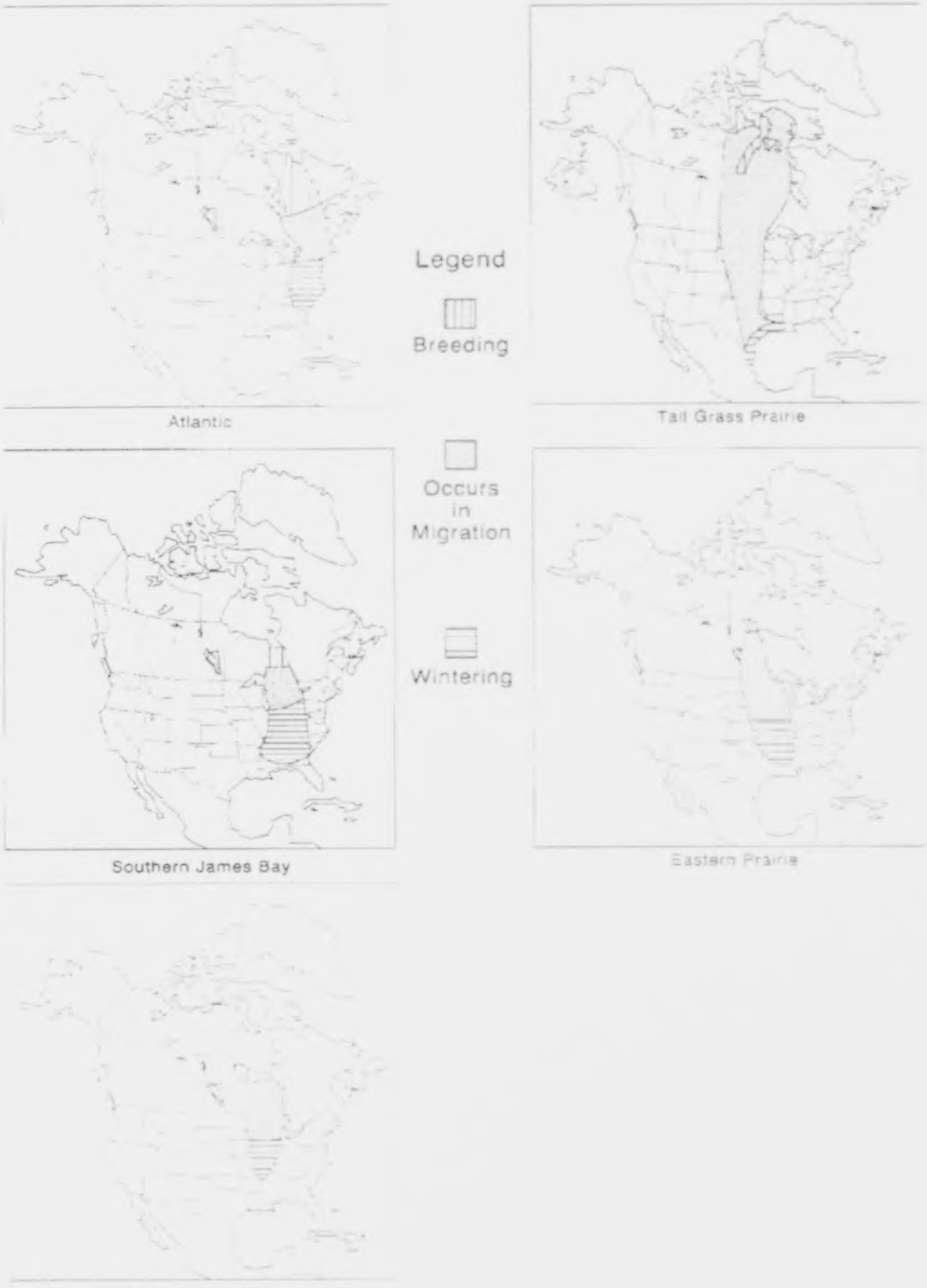
The Canada goose breeds in large numbers though at low densities, in inland marshy areas along the coasts and on the islands of Hudson Bay and James Bay. Nesting initiation dates depend upon weather and can vary by at least a month. On Akimiski Island, for example, nest initiation began as early as 22 April in 1998 and as late as 25 May in 1996 (Leafloor et al. 2000). Numerous studies have been conducted on the growth and development of eggs and goslings (e.g., MacInnes 1962; MacInnes and Misra 1972; MacInnes et al. 1974; Moser and Rusch 1989; Leafloor et al. 2000).

The Canada goose frequents coastal marshes during migration and is a numerous spring and fall transient, particularly along the James Bay coasts (Curtis 1973a+b). There is a northward moult migration of some 30,000 geese past Cape Churchill and the McConnell River to the Thelon River in June (Davis et al. 1985). Its timing varies with the weather and the numbers vary with the previous year's breeding success since most of the moult migrants are immatures. John Rae (1888) described the arrival of the Canada goose at Moose Factory as follows:

> *"This is the earliest of the spring water-fowl migrants, and makes its appearance at Moose, with extreme regularity, on the 23rd of April. So much is this the case that during my ten years stay there, we had a goose at our mess dinner table on St. George's day, first seen and shot on that day; and this I learnt had been the case for a long series of years previously."*

In the Belchers and on Akimiski Island the Canada goose makes extensive use of saline habitats and is characterized by very large salt glands that develop to cope with the high salt intake (Jones and Hanson 1983).

Canada geese that belong to five management populations summer along different stretches of the coastline and winter in different areas of southern Canada and the United States (Figure 10-1). Geese from the Atlantic population that summer in the Belchers and along the Quebec coast, winter along the Atlantic coast from New England to South Carolina (Hanson and Currie 1957; Malecki and Trost 1990; Menkens and Malecki 1991). The number of breeding pairs in this population declined to 29,000 in 1995 and had rebounded to 156,937 ± 12,273 (SE) in 2003 (Dickson 2000; CWS Waterfowl Committee 2003). Geese from the Southern James Bay population that nest on Akimiski Island and along the southwestern coast of James Bay winter from southern Ontario and Michigan to Mississippi, Alabama, Georgia, and South Carolina. In 2003, a spring survey of Akimiski Island and the adjacent lowlands of James Bay produced a population estimate of 106,511 Canada geese. Increasingly large numbers of moult-migrant temperate-breeding Canada geese are moving into this area and into eastern Hudson Bay, where they contribute to high gosling mortality by competing with them for food (Abraham et al. 1999b). Late summer gosling mortality may be a limiting factor in annual productivity of Canada geese on Akimiski Island (Leafloor et al. 1996, 2000). Geese from the Mississipi Valley population that summer along the coast from the Attawapiskat River to the Nelson River winter largely in Wisconsin, Illinois, western Kentucky and Tennessee (Craven and Rusch 1983; Tacha et al. 1988; CWS Waterfowl Committee 2003). The spring population estimate in 2003 was 477,000 geese. Geese from the Tall Grass Prairie population that nest on the Nunavut



Atlantic

Tall Grass Prairie

Southern James Bay

Eastern Prairie

Mississippi Valley

Figure 10-1. Breeding and wintering areas and migration routes of Canada goose populations that nest along the coasts of Hudson Bay and James Bay (from CWS Waterfowl Committee 2003, p. 61-63.)

mainland coast of Hudson Bay from the McConnell River northward, and on Southampton Island winter in Oklahoma, Texas, and northeastern Mexico. Surveys during the brooding period in 2003, resulted in a population estimate of about 100,000 breeding birds. This population is prone to year-class failures; in 1992, 1996, and 1999 almost no young were produced. Geese from the Eastern Prairie population that nest along the Manitoba coast west of the Nelson River winter in Manitoba, Minnesota, and Missouri. In 2003, the spring population was estimated at 229,200 ± 33,500 (95%CI), similar to most years since the mid-1980s. The mean expected lifespan of these geese may be declining (CWS Waterfowl Committee 2003).

The Atlantic, Southern James Bay, Mississipi Valley, and Tallgrass prairie populations likely are composed primarily of the interior subspecies of the Canada goose, *Branta canadensis interior* (Dickson 2000). The Eastern Prairie population consists mainly of the cackling goose *B. hutchinsii* and may include some of the lesser Canada subspecies *B. c. parvipes*.

The coasts of Hudson Bay support over 50% of the eastern Arctic breeding population of the lesser snow goose, *Chen caerulescens caerulescens*, which has increased significantly in the past 30 years (MacInnes and Kerbes 1987; Reed et al. 1987; CWS Waterfowl Committee 2003). Indeed, between 1970 and 1999 there was geometric growth of the mid-continent population of the lesser snow goose, which breeds in the Canadian Arctic and traditionally wintered in the coastal marshes of the Gulf States (Jefferies et al. 2003). This increase was coincident with the increased application of nitrogen to southern farmland and high crop yields, and the widespread availability of agricultural foods has subsidized the energy requirements of these geese for migration and reproduction (Jefferies 2000; Jefferies et al. 2003, 2004). The presence of refugia from hunting on the migration routes, a decline in the harvest rate, and climatic changes that may have caused an anomalous cold area on Baffin Island and a southward shift in nesting locations may also have contributed to population increases along the Hudson Bay coast. Large breeding colonies are dotted along the Hudson Bay coast and the species is locally very numerous, so much so that overgrazing is degrading their prime salt marsh habitats at La Pèrouse Bay, in the McConnell River Migratory Bird Sanctuary, and elsewhere. This problem is discussed in Section 6.5 and has led to the introduction of spring hunts in an attempt to check population growth and avoid a population crash (see also Section 14.6). The current cull may be higher than the replacement rate (Jefferies et al. 2003).

On Southampton Island, the number of nesting lesser snow geese increased from 155,480 birds in 1973 to 720,000 in 1997, and the nesting area expanded (CWS Waterfowl Committee 2003). Large colonies are located at Ell Bay, west of the Boas River, on the Boas River delta, at Bear Cove, and East Bay (Reed et al. 1987) (Figure 10-2). On the Hudson Bay lowlands, surveys conducted between 1996 and 2001 show a decline in the number of pairs nesting in the area between La Pèrouse Bay and Cape Henrietta Maria from a 1997 high of 430,000. In 2003, the breeding population at Cape Henrietta Maria was estimated at 128,000 pairs, a considerable increase from the 1973 estimate of 59,200 breeding adults. Another large population is situated in the Arviat area and partially protected by the McConnell River Migratory Bird Sanctuary (Figure 12-12). In summer, it is common to see adult geese waddling through Arviat trailing their broods. There is also a small breeding colony on Akimiski Island, which increased from less than 200 breeding pairs in 1974 to about 1500 pairs in 2001, and was about the same in 2003 (Abraham et al. 1999a; CWS Waterfowl Committee 2003).

During migration, the entire Foxe Basin population of the lesser snow goose, estimated in 1997 at 1.77 million birds (CWS Waterfowl Committee 2003), stops to rest and feed at marshes on the west coast of James Bay (Gillespie et al. 1991). Nesting in the James Bay and Hudson Bay region begins as soon as bare ground emerges from the melting snow, typically early May to early June (MARC 2003). Numerous studies have been conducted on the growth and development of eggs and goslings (e.g., Ankney and Bisset 1976; Ankney 1980, 1982; Prevett and MacInnes 1980; Williams et al. 1993; Skinner et al. 1998; Badzinski et al. 2001, 2002a+b). Between 1951 and 1986, nest initiation and hatch dates of both lesser snow geese and Canada geese nesting along the Hudson Bay coasts became progressively earlier, possibly in response to climatic amelioration (MacInnes et al. 1990).

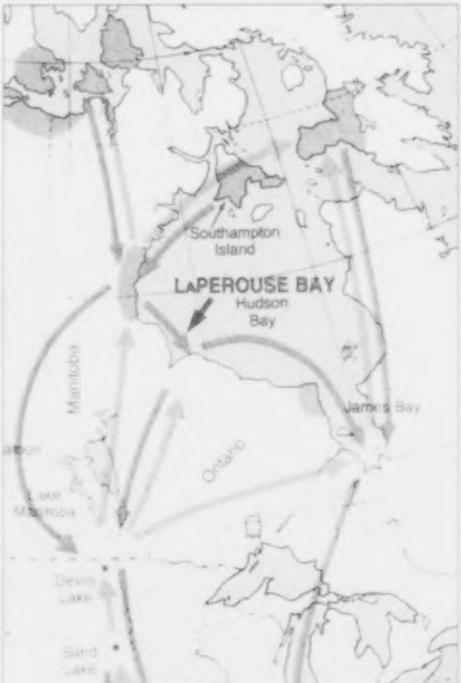


Figure 10-2. **Flyway routes and wintering and breeding areas in North America for populations of lesser snow geese that summer along the coasts of Hudson Bay and James Bay (adapted from Johnson 1996a, p. 21).**

Inuit and Cree observed changes in the migratory patterns of both Canada and snow geese in Hudson Bay and James Bay, ca. 1984 to 1992 (McDonald et al. 1997). More geese of both species migrated further inland from the east coast of James Bay enroute to Hudson Strait and the Arctic. The Canada geese apparently took a more direct route over the La Grande reservoir than the snow geese. At York Factory, where fall migrating Canada geese used to follow the coastline, they began to arrive from the bay, land at Marsh Point, and then head west. Ivujivik, which historically had few snow geese, was overflown by many large flights. Both Inuit and Cree maintain that wind is an important determinant of whether geese follow an inland or coastal migration route. After nesting and moulting, geese in the Cape Henrietta Maria area historically moved inland to feed and then up the southwestern coast of Hudson Bay before migrating south through Hannah Bay. They began to move inland earlier in the 1980s and more remained there to feed until their southward fall migration.

The brant is a saltwater species that breeds widely in the Arctic Islands and along the coastal mainland of the Northwest Territories and Nunavut, nesting on well-vegetated, low-lying coastal tundra. There are small breeding colonies near river mouths along the Kivalliq coast from the McConnell River northward to Chesterfield Inlet, on Southampton and Coats islands, and on Cape Fullerton. The brant colony at the Boas River on Southampton Island supports an estimated 1000 nesting pairs, and constitutes a significant portion of the eastern Arctic breeding population of the Atlantic subspecies, *Branta bernicula hrota* (Müller)(A. Reed, CWS St. Foy, pers. comm. 1991). This colony is at or near the southern limit of the species' breeding range.

Brant migrating to and from their breeding grounds graze extensively on beds of eelgrass along the coasts of James Bay in spring and fall (late September-early November)(Ettinger et al. 1995; Reed et al. 1996a). The distribution of these eelgrass beds is shown in Figure 6-6 of the Plants Chapter, which also discusses their use by waterfowl. During the fall migration over 50% of the Atlantic brant population may use these habitats (Thomas and Prevett 1982). The area south of Roggan River is of national importance because of its extensive eelgrass beds which provide critical feeding habitat for up to 20,000 brant, many thousands of Canada Geese, and numerous ducks--principally black duck, in the fall (Curtis and Allen 1976). Many thousands of brant pass through southern James Bay (e.g., Netitishi Point) on their way south in late fall (McRae 1992). They follow a relatively narrow migration corridor through Quebec enroute to and from their wintering grounds along the Atlantic coast of the United States.

The Ross' goose breeds mainly in the Queen Maud Gulf Bird Sanctuary in the central Arctic, but smaller breeding colonies are found along the west coasts of James Bay and Hudson Bay and on Southampton Island. Nesting has been documented at Akimiski Island, La Pérouse Bay (Ryder and Cooke 1973), McConnell River (MacInnes and Cooch 1963), and on the Boas River delta of Southampton Island (Cooch 1954). In the late 1990s surveys produced an estimate of 40,000 Ross' geese at the McConnell River colony (CWS Wildife Committee 2003). In 2002, up to 2,250 pairs may have nested at Cape Henrietta Maria (Abraham 2002). The species is uncommon in eastern James Bay and has not been reported from the Belchers or the Quebec coast of Hudson Bay.

The greater white-fronted goose is an uncommon to rare, spring or summer transient in western James Bay, southeastern Hudson Bay, and from Churchill northward along the Kivalliq coast. It also occurs on Southampton and Coats islands, likely on enroute to breeding grounds that extend inland from the Kivalliq coast north and west to the Queen Maud Gulf coast and Mackenzie Delta. The species is not common on coastal marine waters, but is a common spring and autumn transient in central Canada. Breeding has been reported in the Repulse Bay area (Snyder 1957).

10.9.2 Swans

The tundra swan is an Arctic-breeding species that was extirpated from the southern shores of Hudson Bay during the early years of the fur trade and is now re-occupying its former range (Heyland et al. 1970, Lumsden 1975, 1984a+b). It breeds throughout coastal areas of the region but is not common along the Kivalliq coast or numerous in general. Small tundra ponds are seldom inhabited by more than one breeding pair. Tundra swans can be seen on open water at the edge of ice floes when they first arrive at Hudson Bay. The trumpeter swan is a rare, non-breeding summer visitor to the Churchill area (MARC 2003).

10.9.3 Dabbling ducks

The northern pintail is the only surface-feeding (dabbling) duck that breeds and is common throughout James Bay and Hudson Bay (Appendix 4). It frequents coastal mudflats, tidal ponds, and brackish ponds in summer (Ross 1984). Moulting flocks of up to 300 pintail have been observed on brackish coastal ponds along the northern coast of Ontario in late summer (Prevett in Ross 1982). Flocks of up to 5,000 migrants occur at the mouth of the Moose River in late September and early October (Lewis and Peters 1941).

The green-winged teal, American black duck, mallard, and American widgeon are common breeding species in James Bay and along the Ontario coast of Hudson Bay, but are increasingly rare north of the treeline. Only the first two species occur offshore on the Belchers. The blue-winged teal and northern shoveler are also common breeding species along the western coast of James Bay but are uncommon to rare elsewhere within the treeline and absent further north. The gadwall is a rare summer visitor to James Bay and Churchill, while Eurasian widgeon have only been reported from the Churchill area.

The green-winged teal is generally seen in dense flocks on the mudflats beside streams and river mouths, or inland on brackish ponds (Ross 1984). Over 10,000 birds were seen during the fall migration near Chickney Point on 14 September 1978. The black duck is very common in eastern James Bay, where it tends to occur around river mouths and estuaries, usually in more saline habitats (Reed et al. 1996b; Figure 10-3). It feeds extensively on mudflats when invertebrates are exposed by the falling tide, and on eelgrass that is exposed at particularly low tides. The black duck is particularly numerous in August and September when females join the males and non-breeding females along the coast. The American widgeon and blue-winged teal occur and breed largely in southern and western James Bay, where they are common and locally abundant. The American widgeon is present in large numbers only in autumn migration, when it is seen most often on brackish water habitat associated with stream mouths, including mudflats and goose meadows (Ross 1984). The preferred habitat of the northern shoveler appears to be fresh or brackish ponds contained by beach ridges or at the back of the coastal marsh. The mallard and blue-winged teal are the least common of these species in saltwater habitats.

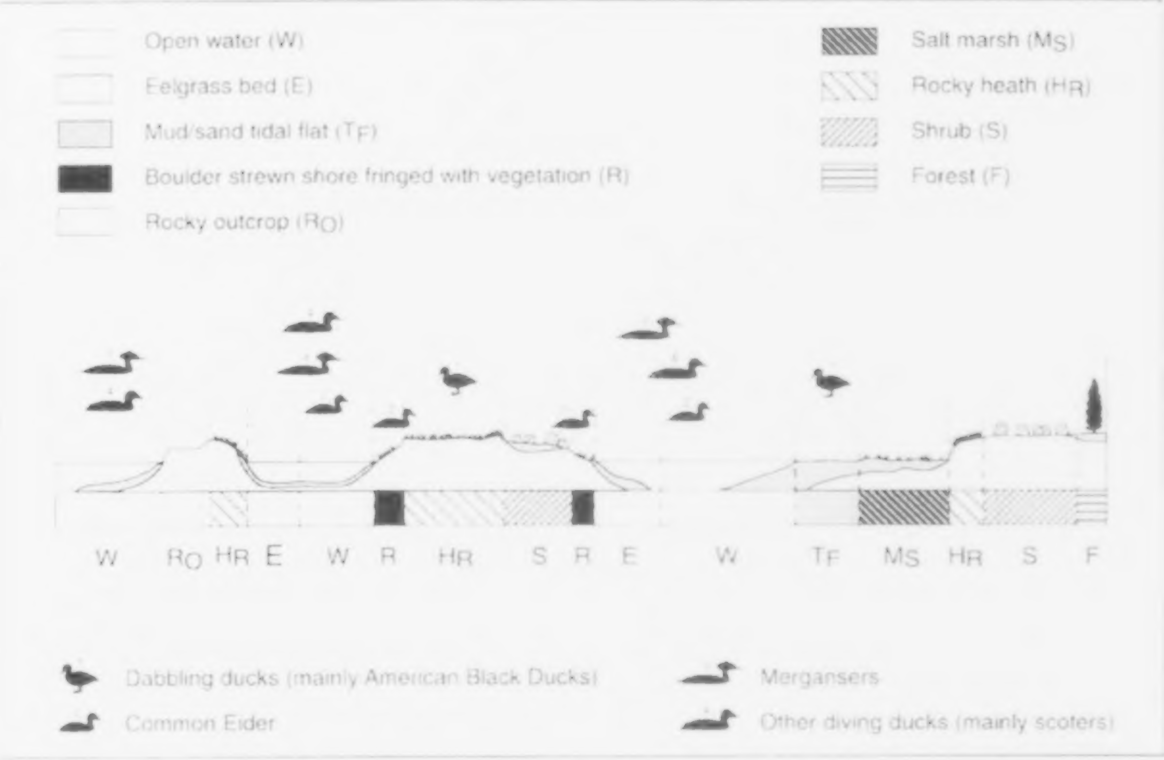

Open water (W)
Eelgrass bed (E)
Mud/sand tidal flat (TF)
Boulder strewn shore fringed with vegetation (R)
Rocky outcrop (RO)
Salt marsh (MS)
Rocky heath (HR)
Shrub (S)
Forest (F)
W RO HR E W R HR S R E W TF MS HR S F
Dabbling ducks (mainly American Black Ducks)
Common Eider
Mergansers
Other diving ducks (mainly scoters)

Figure 10-3. Use of habitats of the northeast coast of James Bay by ducks (from Reed et al. 1996b).

10.9.4 Eiders

The Hudson Bay subspecies of the common eider, *Somateria mollissima sedentaria* Snyder, lives year round in Hudson Bay and James Bay. Nakashima and Murray (1988) have provided an excellent, thorough overview of eider biology in this region, based on both scientific surveys and Inuit knowledge. These studies have been followed up by those of Robertson and Gilchrist (1998) and Gilchrist and Robertson (1999, 2000). The common eider feeds almost exclusively on blue mussel (*Mytilus edulis*) (A. Reed, CWS, Ste. Foy, pers. comm. 1992), and typically occurs in summer in open water or along rocky shores (Figure 10-3). It breeds locally and commonly (colonial) along low-lying, tundra, or rocky coasts throughout Hudson Bay and James Bay. The presence of a fox can severely limit eider nesting success on smaller islands.

In the mid-1980's the breeding population in eastern Hudson Bay was estimated at 83,000 birds--most of which occurred in southeastern Hudson Bay (Nakashima and Murray 1988). These birds overwinter in Hudson/James Bay where open water and shallow depth coincide (Sutton 1932; Snyder 1941, 1957; Freeman 1970a+b; Schmutz et al. 1983; Abraham and Finney 1986; Nakashima and Murray 1988). Inuit report that they are present, sometimes in quantity, at almost every ice edge that is accessible from Sanikiluaq in winter, and in a number of polynyas (Figure 5-7; Nakashima 1988). In the winter of 1991-92 eiders were found frozen into areas where, historically, the water has remained open in winter (P. Kattuk, Mayor of Sanikiluaq and Z. Novalinga, Sanikiluaq Environmental Committee, pers. comm. 1993). The Inuit attributed these kills to decreases in the area's winter currents (MacDonald et al. 1997). Subsequent scientific studies estimated that the number of nesting eiders declined 75% from 1985-88 to 1997 decline in the number of nesting eiders (Robertson and Gilchrist 1998). This raised serious conservation concerns, because eider populations are sensitive to reductions in adult survival and subsistence hunters harvest this population throughout the year.

Overwintering concentrations of eiders have been reported near the Belchers (Freeman 1970a+b; MacDonald et al. 1997; Gilchrist and Robertson 2000), at Cape Henrietta Maria and in shore leads along the west coast of Hudson Bay (Abraham and Finney 1986), and offshore Churchill (MARC 2003). Manning (in Bray 1943) also reported eiders "probably *sedentaria*" overwintering off Cape Fullerton. In March of 1998 and 1999, large flocks of common eiders (200-12,500 birds) were seen along landfast ice edges around the Belcher Islands, and small groups occurred in some polynyas (Gilchrist and Robertson 2000).

The king eider is uncommon but widely distributed in James Bay and Hudson Bay. It breeds primarily in the Arctic, but does nest along the James Bay and Hudson Bay coasts. Unlike common eiders, which often breed in colonies, king eiders are solitary nesters (MARC 2003). Most of the eastern king eiders winter between Greenland and New England, but a few remain with common eiders on Hudson and James bays (Gilchrist and Robertson 2000).

Both eiders frequent coastal marine waters throughout the breeding season, and common eider are sometimes found well off shore.

10.9.5 Mergansers

Three species of these piscivorous, diving ducks feed in the estuaries and coastal waters of James Bay and Hudson Bay in summer (Figure 10-3). The red-breasted merganser is common along the coasts of James Bay and southwestern Hudson Bay, less so north of the treeline. It nests on the ground and breeds widely in the region, typically near freshwater streams and lakes. Males, after early summer, and non-breeding birds frequent coastal marine waters. Flocks of 50-200 birds, presumably moulting, are often found on the Churchill River and Hudson Bay in midsummer (Jehl and Smith 1970). The species abundance may have declined dramatically in the Churchill area since the 1940s (MARC 2003). The common and hooded mergansers have more southerly distributions and nest in tree cavities. The former is uncommon or absent in western and northern Hudson Bay, but common elsewhere. It typically nests further south and inland from the coast. The hooded merganser is a rare, non-breeding visitor to James Bay and the Churchill area.

10.9.6 Other diving ducks

Long-tailed duck (formerly oldsquaw) breed throughout the region (Appendix 4). They arrive at Churchill as early as ice conditions permit and by late May can be observed courting in leads on the Bay (Jehl and Smith 1970). The most southerly breeding populations of this species are found at Cape Henrietta Maria, and on Akimiski, Bear, Grey Goose, and South Twin Islands in James Bay. In the Churchill area, nests are found most commonly on islands in freshwater tundra ponds or lakes, but also in upland tundra, marshes, and even spruce forest—usually within 10 m of water and sometimes grouped together (Allison 1975b as cited in MARC 2003). Flights of over 500 long-tailed ducks pass through southern James Bay in late fall, where over 10,000 birds can sometimes be seen in a single day (McRae 1992; Abraham and Wilson 1997). They have been seen at Churchill on the 3rd of November 1963 (MARC 2003), and at Moosonee on the 4th of December 1994 (Abraham and Wilson 1997). Flocks of long-tailed ducks (100-500 birds) were common in polynyas near the Belcher Islands in March of 1998 and 1999 (Gilchrist and Robertson 2000). Some individuals also overwinter on open water of James Bay (Godfrey 1986).

Greater and lesser scaup and common goldeneye breed, and typically are common, along the southern and western coasts of James Bay and the southwestern coast of Hudson Bay. The greater scaup is uncommon but also breeds along the mailand coast of southeastern Hduson Bay and Nunavut, north to Rankin Inlet. It is most common in western James Bay, and is one of the commonest breeding ducks at Churchill (Jehl and Smith 1970). The lesser scaup and ring-necked duck breed largely in southern and western James Bay. The former is common and locally abundant, the latter uncommon. Occasionally, the common goldeneye is common on the Churchill River estuary (Jehl and Smith 1970).

The surf, white-winged, and black scoter are also common on the Belchers and along the coast from southeastern Hudson Bay west to Churchill. In the Belchers and along the Quebec coast of Hudson Bay these species typically are non-breeding transients. Surf and white-winged scoters nest on the Twin Islands, along the east coast of James Bay, and inland from the western James Bay and southeastern Hudson Bay coasts. Non-breeding and post-breeding male scoters are common on coastal waters during the summer, and this region provides very important moulting habitat for the species (A. Reed, CWS, Ste. Foy, pers. comm. 1992) (Figure 10-3). Indeed, Ross (1983) counted 42,600 moulting male black scoters along the northern James Bay coasts between Ekwan Point and Hook Point and another 16,700 at Cape Jones. In July 1977, 43,700 moulting male black scoter were seen on Hudson Bay near the mouth of Shell Brook, Ontario (Ross 1983). Some of these birds may winter on the Bay. While the black scoter is the most common diving duck along the Ontario coast (Ross 1982), it breeds inland and has not been reported to breed along the coasts (Ross 1983; Savard and Lamothe 1991). The black scoter may overwinter in small numbers in James Bay (Ross 1983). All three scoters are common along the Atlantic and Pacific coasts of Canada, but only the white-winged scoter is common in central Canada.

The harlequin duck occurs mainly along the Atlantic and Pacific coasts and is a rare summer visitor to Hudson Bay and James Bay. It has been reported from Churchill and is uncommon but nests in the Richmond Gulf area (Lac Guillaume Delisle). The species may be more common along the Quebec coast of the region (A. Reed, CWS Ste. Foy, QC, pers. comm. 1992). The Atlantic population has been designated "Special Concern" by COSEWIC, on the basis of its population small size and tendency of the species to congregate in relatively large groups when mating and wintering, which makes it succeptible to catastrophic events such as oil spills ([illegible]).

Bufflehead, Barrow's goldeneye, canvasback, redhead, and ruddy duck are rare summer visitors. Most have only been reported from southern James Bay and/or the Churchill area. Buffelhead and canvasback have nested at Churchill.

10.10 F. ACCIPITRIDAE: Ospreys, Eagles, Hawks, and Harriers

Accipiters make limited use of the Hudson Bay and James Bay coasts. Osprey, northern harrier (marsh haw), sharp-shinned hawk, and bald and golden eagles hunt or scavenge along the coast on occasion, while northern goshawk and rough-legged hawk generally hunt inland--all are summer residents and widely distributed in southern Canada. Only the northern harrier, which preys on shorebirds and waterfowl, is a common ground nester in the coastal salt marshes of Hudson Bay and James Bay. Northern harriers arrive at Churchill in May and migrate southward through the area from mid-August to mid-September (MARC 2003). The other species may nest on coastal cliffs or in trees on occasion. At Churchill, rough-legged hawks apparently nest wherever the can find an elevated spot, on the grain elevator, discarded oil drums, the rocket launching gantry, the garbage incinerator, and even on the shipwrecked Ithaca (MARC 2003). Southward migrating northern harrier, northern goshawk, and rough-legged hawk are common in late fall in the Hannah Bay area of southern James Bay (McRae 1992).

10.11 F. FALCONIDAE: Falcons

Four falcons hunt shorebirds and waterfowl along the coasts of James Bay and/or Hudson Bay. The merlin and peregrine falcon, breed and hunt along the coasts of Hudson Bay and James Bay in summer, while the gyrfalcon is a year-round resident of Nunavut and northern Quebec, and an occasional late fall migrant or winter visitor to the southwestern coast of Hudson Bay and James Bay. The prairie falcon is a rare summer visitor to the Churchill area.

The merlin generally nests in trees, but will occasionally nest on cliffs or on the ground. It occurs north to Manitounuk Sound along the east coast of Hudson Bay, and to the southern Kivalliq in the west. The species is most abundant during migrations of shorebirds and other small birds on which it feeds.

Peregrine falcon populations have been depleted severely by the effects of DDT, which they accumulate from their prey. They breed in areas with high to moderate relief along the Hudson Bay coast of Manitoba, Nunavut, and northern Quebec and on Southampton, Coats and the Belcher and Nastapoka islands (see also Fyfe 1969; Albright and Doidge 1992). Nests are situated on cliff ledges, often near seabird colonies. Peregrines inhabiting coastal areas in summer prey on shorebirds, seabirds, and small mammals, which they kill with a blow from their feet following a spectacular dive (Fleck 1981; Court et al. 1988). The species is uncommon to rare along the James Bay coast during breeding season but southern James Bay is a favorite resort in the fall, when migrating shorebirds and ducks are abundant. Todd (1963) identified peregrines in this region as *Falco peregrinus anatum*. This subspecies has been designated as "Threatened" by COSEWIC.

Figure 10-4. Peregrine falcon near Rankin Inlet (photo credit D.B. Stewart).

There is a dense, productive population of the more northerly distributed subspecies of peregrine falcon, *F. p. tundrius*, on coastal cliffs and islands near Rankin Inlet on the Kivalliq coast (Court et al. 1988, 1989) (Figure 10-4). COSEWIC lists this subspecies as "Special Concern". These birds arrive on the breeding grounds in mid-May from wintering areas as far south as Uruguay. Production has fluctuated around the mean of ~30 fledglings produced per year (Setterington 2004). The population has relatively low pesticide residues and high reproductive success, but there is still measurable pesticide-related egg thinning and between 1981-6 about 10% of the breeding pairs failed due to egg breakage (Court et al. 1990). A decade later, there had been little improvement in the pesticide loads (Johnstone et al. 1996). The birds were still accumulating organochlorine pesticides on their wintering grounds and from aquatic prey taken in North America. In 2003, there were 25 active nests within an 18 km^2 radius of Rankin Inlet and 26 chicks were fledged (Setterington 2004). The area has one of the highest and best-known concentrations of peregrines in the world and should be considered for protection (M. Bradley, GNWT Renewable Resources, Arviat, pers comm.; R. Bromley and C. Shenk, GNWT Renewable Resources, Yellowknife, pers. comm.). Peregrines also nest further north in the vicinity of Scarab Point and nearby Rabbit Island, to the south toward Whale Cove, and offshore on Marble Island.

Mature gyrfalcons are the only raptors that are permanent residents of Nunavut (Fleck 1981). They breed near the Hudson Bay coast in Kivalliq and northern Quebec, and on Southampton, Coats, and Mansel islands but are not common or abundant. Nests are situated on inaccessible cliff faces, and when they are located in coastal areas the falcons prey primarily on seabirds, which they attack from the air. Overwintering adults remain close to the nesting area and prey on ptarmigan or hares. Gyrfalcons arrive in southern James Bay in late October, where they patrol the coast in the East Point and Netitishi Point areas (McRae 1992).

10.12 F. RALLIDAE: Rails, Gallinules, and Coots

Rallidae are predominantly marsh birds. Three species near the northern limits of their distributions, the yellow rail, sora, and American coot, are summer residents along the James Bay and southwestern Hudson Bay coasts. Yellow rail and sora are common in some locales, and breed in the tidal marshes of James Bay and southern Hudson Bay west to Churchill. Indeed, the Hudson Bay coast may be the breeding "stronghold" of the yellow rail in Ontario (Cadman et al. 1987). The sora also breeds along the Quebec coast north to Kuujjuarapik. The American coot is an uncommon visitor to the southern tip of James Bay, where it may breed, and is rare but nests at Churchill. All three are common breeding species across most of southern Canada.

The yellow rail has been designated a species of "Special Concern" in Canada by COSEWIC. The relatively small population is declining due to loss of its limited wetland wintering habitat in the southern United States by land drainage and, to a lesser extent, degradation of its summer breeding habitat by goose overgrazing. Further decline could go undetected because of the secretive nature of the species.

10.13 F. GRUIDAE: Cranes

Sandhill cranes are summer visitors to the southern and western coasts of James Bay and Hudson Bay, from Boatswain west and north. They have also been reported from the Belchers and Southampton Island. While widely distributed, these birds are seldom abundant. They nest in marshy low-lying areas and sometimes eat young snow geese or scavenge fish remains left by fishermen (Mallory 1987). Cranes pass Churchill going north in May and going south in September (Jehl and Smith 1970).

The crane population of the Hudson Bay Lowland was extirpated in the 19th century. The area was likely re-colonized by birds from the west that do not follow the migration route of the former population through southern and central Ontario. Crane sightings were rare on surveys of the James Bay coast between 1950 and 1970, however the population began to increase rapidly in the 1970's. This trend continued and, in the early 1980's, over 200 cranes were sighted along the Ontario coast between Ekwan Point and Hook Point in a single day (Abraham in Cadman et al. 1987).

10.14 F. CHARADRIIDAE: Plovers

The American golden-plover, killdeer, and semipalmated plover summer and breed along the shores of Hudson Bay and James Bay, while the black-bellied plover is a common non-breeding transient in James Bay that breeds on the shores of northern Hudson Bay. The use of coastal habitats in western James Bay by black-bellied and semipalmated plover is discussed further in the Section 6.5. Plovers do not overwinter in the region. Several American avocets (*Recurvirostra americana* Gmelin) have strayed to Churchill, but the species typically feeds at the edge of fresh, rather than salt water.

The black-bellied plover is a truly Arctic shorebird that nests on Southampton Island and further to the north, typically on dry gravel ridges or wetter tundra. It is a common species in spring and fall on the flats and pebbly beaches of southern James Bay where it finds suitable feeding and resting grounds. The species migrates northward along the mainland coasts from late May through mid-June and returns southward from mid-August through early October. The spring migration from coastal northeastern United States appears to be mainly to the muddy coastal flats, pools, beaches, and sandbars of James and Hudson bays. Historically, the black-bellied plover was very abundant on the Hudson Bay coast, where Hearne and others hunted it extensively for food (Manning 1952). The average number consumed annually at York Factory over a 5-year period ca. 1860, was 2480.

The American golden-plover breeds at Cape Henrietta Maria, from Churchill northward along the west coast of Hudson Bay, and on Southampton Island. These areas are near the southern limit of the species' breeding range, but it is becoming an increasingly common breeder in the Churchill region (MARC 2003).

American golden-plovers tend to prefer drier habitat than the black-bellied plovers but are also found along coastal shores and beaches. The species' "run-stop-peck" feeding pattern makes it an attractive "watchdog" for shorebirds such as dunlin and short-billed dowitcher that feed by probing, and the species are often closely associated (Byrkjedal 1987). Migrants pass northward through Churchill in late May and early June and more return southward from mid-August through mid-September (Jehl and Smith 1970). Twomey (1938 cited in Todd 1963) saw about 75 birds at Eskimo Harbour in the Belchers on 26 August. They are regular but uncommon autumn transients along the west coast of James Bay. The American golden-plover undertakes a remarkable 4,000 km non-stop migration in the fall from the rich feeding areas around Hudson Bay over the Atlantic Ocean to South America (Figure 10-5).

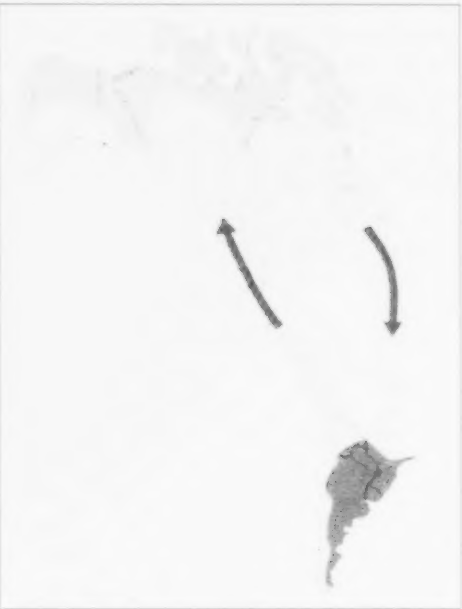


Figure 10-5. **Migration path of the American golden-plover (from Elphick et al. 2001, p. 264)**

The semipalmated plover breeds, and is common and numerous, in low-lying coastal areas of Hudson Bay and James Bay. It frequents salt mud flats and beaches, and nests in shallow depressions in the sand, gravel, moss, or dead seaweed. Along the seashore these birds eat small molluscs, marine worms, small crustaceans, and eggs of marine animals. Migrants arrive in the Churchill area in late May and by early August most adults have left the area; young begin migrating southward in mid-August and a few remain into September (Taverner and Sutton 1934; Jehl and Smith 1970). Semipalmated plovers are spring and fall transients throughout most of southern Canada and also breed in the maritimes.

The killdeer breeds along the southern and western coasts of James Bay and Hudson Bay from Boastwain Bay west to Churchill. This is the northern edge of its breeding range in central Canada. The species is seen occasionally along coastal beaches or in salt marshes.

10.15 F. SCOLOPACIDAE: Sandpipers, Phalaropes, and allies

Species of this family of shorebirds exhibit a wide range of sizes and colors; most are gregarious and frequent shores and marshy areas (Snyder 1957; Godfrey 1986). Twenty-five species breed along the coasts and frequent coastal or offshore habitats during the summer, and several are spring and/or fall transients--none overwinters (Appendix 4). Many of these shorebirds make a direct flight from James Bay to the Atlantic seaboard or, in the case of Hudsonian godwit, to South America. They require fat built up from feeding along the James Bay coast to fuel them on the flight (Martini et al. 1980b). This coastal ecosystem provides resources of critical international importance for the Hudsonian godwit and red knot (Morrison 1983). The endangered Eskimo curlew was reported from near Hannah Bay in 1976 (Hagar and Anderson 1977).

10.15.1 Species with wide breeding distributions

The semipalmated sandpiper, least sandpiper, and red-necked phalarope have wide breeding distributions along the coasts of James Bay and Hudson Bay. During breeding season they frequent mostly coastal areas that have moist to wet vegetated tundra, and sometimes salt marshes or higher, drier areas with low vegetation.

The semipalmated sandpiper has a wide breeding distribution in Arctic and Subarctic Canada, and nests along the coasts of James Bay and Hudson Bay, except perhaps on Mansel Island and on low-lying coastal sections. Most semipalmated sandpipers along the west coast of James Bay feed on the shortgrass salt marsh

(*Puccinellia phryganodes*), where they prey on dipteran larvae (Martini et al. 1980b) (see also Section 6.5). At Churchill, the males arrive about 24 May to establish breeding territories, and are followed a few days later by the females (MARC 2003). The first eggs are laid between 7 and 23 June and hatch in late June or early July. Wet, coastal sedge meadow is the preferred nesting habitat. Once the most abundant breeding shorebird near Churchill, the nesting frequency of the semipalmated sandpiper has declined dramatically since the 1930's, for reasons that are uncertain (MARC 2003). The adults migrate southward in great numbers along the west coast of James Bay in the latter half of July enroute to the northern coast of South America (Hope and Shortt 1944; Morrison 1983). Some flocks may contain up to 5000 birds. The least sandpiper is a common breeder across Subarctic Canada and on the mainland shores of Hudson Bay south of Chesterfield Inlet in the west and Inukjuak in the east, but rarely on the Belchers or the islands of northern Hudson Bay. The red-necked phalarope breeds along reaches of coastline throughout the region, and across northern Canada. It is a swimming shorebird that migrates over the open ocean and coastal waters and comes inshore mainly to weather storms. It is rare in the interior. Flocks of over 1000 young red-necked phalarope have been observed on large ponds near Churchill in August (Jehl and Smith 1970).

10.15.2 Species near the northern limit of their breeding range

Species that are at the northern limit of their breeding range in the Hudson Plains or Taiga Shield coastal ecozones of Hudson Bay or James Bay coast (Figure 4-12), include the greater and lesser yellowlegs, solitary and spotted sandpipers, whimbrel, Hudsonian and marbled godwits, short-billed dowitcher, Wilson's snipe, and Wilson's phalarope. These species sometimes forage in coastal habitats and generally have widespread breeding distributions in the subarctic and/or to the south, often across Canada. Most are common on coastal mud flats and beaches during their migrations, and sometimes in salt marshes. They favour well-defined zones of marsh or flats for feeding and resting, and resource partitioning on the basis of habitat or food type or size is apparent throughout the James Bay shorebird community (Figure 6-8) (Martini et al. 1980b).

The southwest coast of Hudson Bay from Cape Henrietta Maria north to Rankin Inlet is one of two disjunct breeding areas in Canada for the whimbrel, the other being in the Mackenzie Delta region. Flocks of whimbrels normally arrive at Churchill in late May (Jehl and Smith 1970). Breeding is common at Churchill and La Pérouse Bay, with peak hatching in late June and early July (MARC 2003). Whimbrels also have been reported on Southampton Island during the breeding season. Small flocks begin to migrate southeastward along the Hudson Bay coast in the third week of July, with numbers peaking in August, and few in September. Birds from the Hudson Bay subspecies or population spend the winter on the Atlantic and Gulf coasts of the Americas (Morrison et al. 2001).

The western coast of James Bay and southern coast of Hudson Bay provide resources of critical international importance for the Hudsonian godwit (Morrison 1983). The species is dispersed through central Canada during its spring northward migration but the autumn migration is concentrated in a narrow lane down the west coast of Hudson and James bays. Small northward-migrating flocks begin arriving at Churchill in late May (Jehl and Smith 1970). The main body of southward-migrating adults reaches the coasts of James Bay in late July and August (see also Hope and Shortt 1944). The migrants settle in large groups on tidal flats to feed and build up fat reserves before departing in late August for South America. The most spectacular discovery was of an estimated 10,000 Hudsonian godwit north of the Albany River in 1974 (Morrison and Harrington 1979). This represents about 30% of the species' Atlantic coast and South American wintering population, and makes the area one of critical importance for the species (Curtis and Allen 1976). Young-of-the-year gather on the west coast of James Bay in early September and depart from mid-September to early October. Both adults and young appear to fly nonstop from James Bay to South America. The Hudsonian godwit is uncommon except on the breeding grounds and main migration route. The species' breeding range is poorly known, but it does nest in the Cape Henrietta Maria area and along the northern coast of Manitoba from York Factory to Churchill.

The importance of the region to the remaining species varies. The Wilson's snipe, known until recently as the North American race of the common snipe (MARC 2003), has a widespread breeding distribution along the coasts of James Bay and southern Hudson Bay. Like geese, it makes extensive use of brackish marsh habitat (Martini et al. 1980b). The species normally reaches Churchill in late May or early June, and some individuals remain until early October (MARC 2003). The greater yellowlegs has a similar breeding distribution but is common further north along the Quebec coast and offshore on the Belcher Islands. The spotted sandpiper breeds on mainland coasts north to Richmond Gulf and is uncommon further north. It is more common in coastal freshwater than marine habitats. The lesser yellowlegs and short-billed dowitcher also breed along the coasts of James Bay and the southwestern coast of Hudson Bay. The lesser yellowlegs is an abundant fall migrant in southern James Bay. The short-billed dowitcher is a regular spring and fall transient along the west coast of James Bay, and a locally plentiful autumn migrant along the Hudson Bay coast where it feeds along the edge of mud flats or sedge meadows. A population of marbled godwit, nests on Akimiski Island and along the nearby mainland of western James Bay. This is unusual since the species normally nests on the prairies. The solitary sandpiper breeds but is not abundant along the coasts of James Bay and southwestern Hudson Bay. It is present at Churchill from the end of May until late August (MARC 2003). Wilson's phalarope is an uncommon species that normally nests in central North America, but occasionally nests along the west coast of James Bay.

10.15.3 Species near the southern edge of their breeding range

The remaining species breed mainly in the Arctic. Some also nest on the tundra along the northwestern coast of Hudson Bay and/or on the northern islands, which are near the southern limits of their breeding range. The dunlin breeds along coasts from eastern James Bay west and north to Southampton and Coats islands. It is a common spring migrant along the Hudson Bay coast from late May to mid-June, and up to 700 birds sometimes congregate at Bear Cove, near Churchilll in June. Most breeding adults leave Churchill by mid-July, whereas juveniles remain until September (MARC 2003). The species moults before migrating south so both juveniles and adults remain along the James Bay coast until mid-September (Morrison 1991). The pectoral sandpiper breeds at Cape Henrietta Maria, along the Kivalliq coast, and on Southampton and Coats islands. It is an uncommon spring migrant at Churchill in June, enroute to the Arctic, and returns southward from early July through early September. The red phalarope breeds along the Kivalliq coast, the northern coast of Quebec south to Ivujivik, and on Southampton, Coats, and Mansel islands. Like the red-necked phalarope, it is a swimming shorebird that migrates over the open ocean and coastal waters and comes inshore mainly to weather storms. It is a rare visitor to southern James Bay and migrates mainly along the Atlantic and Pacific coasts.

Ruddy turnstone, red knot, sanderling, and white-rumped sandpiper are common migrants along the coasts of Hudson Bay and James Bay. Flocks of over 10,000 ruddy turnstones arrive at Churchill in late May to mid-June (MARC 2003). These are the largest concentrations of the species recorded in Canada. Most continue northward. Small flocks are observed at Churchill from mid-July through mid-September. Up to 7,000 red knots, representing 10-20% of the South American wintering population, settle on the extensive sandflats of southern James Bay to feed enroute from the Arctic to the Atlantic coast and then to South America (Morrison and Harrington 1979; Morrison and Ross 1989; Morrison et al. 1991) (see also Section 6.5). Many red knots skirt the west coast of Hudson Bay on their way north (MARC 2003). The species has specialized habitat requirements and is easily disturbed. The sanderling is a common spring migrant along the coast near Churchill enroute to its breeding grounds in the Arctic. The spring migration at Churchill peaks about 10 June, and the fall migration extends from mid-July to mid-September, with flocks of several hundred in late-July (Jehl and Smith 1970). The purple sandpiper is unusual among these species in that it also breeds along the Quebec coasts of James Bay and southeastern Hudson Bay, and on the Belchers. It migrates mainly east of Hudson Bay along the coasts and seldom strays far from salt water. The white-rumped sandpiper is a fairly common spring migrant along the coast near Churchill from late May through early June (MARC 2003). The species frequents wet, sandy areas and mudflats, often feeding belly-deep in water. The fall southward migration at Churchill extends from late July to October, and can be impressive. Three thousand white-rumped sandpipers were seen there on 9 October 1986.

Baird's, buff-breasted, and stilt sandpipers migrate mainly through the interior west of Hudson Bay and are less common migrants along the coasts. During migration, these shorebirds favour a variety of coastal habitats, often including mud flats, muddy shores, beaches, and sometimes seaweed-covered rocks. The Baird's sandpiper is less inclined to feed in water than most other sandpiper species. It is a common spring migrant at Churchill between 24 May and 24 June but is uncommon to rare during the fall migration, which extends from mid-July to mid-October (MARC 2003). The stilt sandpiper is more common in coastal freshwater habitats. It arrives in the Churchill area in late May and early June. The species breeds along the southern coast of Hudson Bay from Cape Henrietta Maria west to the McConnell River. Most adult females leave Churchill by 12 July and males by 20 July; the juvenile migration peaks in early August. The number of stilt sandpiper nests in the Churchill area appears to have declined substantially since the 1930's. The buff-breasted sandpiper is not known to breed along the Hudson Bay or James Bay coast. Its main northward migration route is west of Churchill, but strays occur there in mid-June (MARC 2003). The little stint is uncommon to rare and has only been reported from southwestern James Bay. It does not breed in this region.

10.16 F. LARIDAE: Jaegers, Gulls, and Terns

Jaegers are graceful, gull-like, predatory seabirds that often rob gulls and terns for food. They spend most of the year on the ocean but nest on the Arctic tundra. The parasitic jaeger breeds on the islands and along the coasts of Hudson Bay, the Pomeranian jaeger along the Quebec coast of Hudson Bay and on Southampton Island, and the long-tailed jaeger there and along the Kivalliq coast. All three occur along the southeastern coast of Hudson Bay. They have wide Arctic breeding distributions, and migrate and winter mainly at sea along the Pacific and Atlantic coasts. Parasitic jaegers arrive at Churchill in late May or early June and leave by mid-September (MARC 2003). Pomeranian and long-tailed jaegers are rare or absent in James Bay.

Of the gull species, only the herring gull breeds along coasts throughout Hudson Bay and James Bay in summer. Pairs nest singly or in colonies, often with other gulls or terns, and frequent coastal waters. The herring gull is a common breeder and/or transient throughout southern Canada. It arrives at Churchill and Richmond Gulf as early as late April and leaves Moosonee area by early November. Individuals have remained in the Churchill area until 11 December (Jehl and Smith 1970).

Iceland, glaucous, and Sabine's gulls breed along the northern coasts of Hudson Bay, and widely in the Canadian Arctic. The glaucous gull also breeds on the Belchers and along the southeastern coast of Hudson Bay from Richmond Gulf northward. It generally nests in colonies on cliffs and some individuals winter in Hudson Bay, although most winter along the Atlantic and Pacific coasts. Thayer's gull (*Larus thayeri* Brooks) is treated here as a subspecies of the Kumlein's race of the Iceland gull (*L. glaucoides kumlieni*), with which it interbreeds in cliff-nesting colonies on Southampton and Coats islands (Gaston and Decker 1985; Gaston et al. 1986). Twomey reported the Iceland gull (in Todd 1963) from Ney Island in the Belchers in late May 1938, and a dead specimen was found south of Cape Henrietta Maria (Peck 1972). The Sabine's gull often nests with Arctic terns on low, wet coastal tundra, and is a rare fall visitor to James Bay. Glaucous and Iceland gulls migrate and generally winter along the Atlantic and Pacific coasts, while the Sabine's gull migrates and winters along the Pacific coast. These species frequent coastal waters outside the breeding season, and are rarely seen in the interior of Canada.

The number of herring and glaucous gulls nesting in the Belcher Islands declined between 1985-88 and 1997 (Gilchrist and Robertson 1999). The causes of these declines are unknown but the reproductive success of these gulls may have declined in response to a 75% decline in the region's nesting eider population, since eider eggs and young are an important food source for gulls during the breeding season (see also Robertson and Gilchrist 1998).

Ross's and ivory gulls are rare spring visitors to Hudson Bay and James Bay. The Ross's gull will nest at Churchill (Chartier and Cooke 1980) and occurs in summer at the McConnell River in the Kivalliq. The species usually nests in the Canadian high Arctic and in Siberia, may overwinter at Arctic polynyas, and is rare in southern

Canada. The ivory gull may occur more widely and in both summer and winter, but breeds further north. The Ross's gulls has been designated "Threatened" by COSEWIC, on the basis that very few individuals occur in Canada where they breed in very few places (two known sites), and that recolonization could be slow if these sites were abandoned (http://www.cosewic.gc.ca). The ivory gull has been designated "Special Concern" by COSEWIC, on the basis that there are few in Canada and, in summer, the species is susceptible to human activities and disturbance. During the rest of the year, its tendency to congregate makes it vulnerable to oil pollution.

The great black-backed gull, which breeds along the Atlantic coast, has apparently moved into southeastern Hudson Bay in recent years where it is an uncommon visitor to the Quebec coast (Savile 1950; A. Reed, CWS, Ste. Foy, pers. comm.) and occasional visitor to Churchill (MARC 2003). The California gull, which nests in western Canada, has been reported at Ekwan Point (OMNR 1991) and Churchill (MARC 2003). The glaucous-winged gull, which typically lives and breeds along the west coast of North America, also occurs accidentally at Churchill (MARC 2003). Breeding has not been reported along the coasts of Hudson Bay or James Bay for these species.

The Bonaparte's gull breeds at Churchill. It is a common breeder and transient south of the treeline in southern James Bay, and in western and central Canada. It arrives at James Bay in mid-May and departs by mid-October. Nests are built in the vicinity of muskegs, ponds, and lakes in coniferous woodlands. Post-breeders and non-breeders frequent coastal areas. The ring-billed gull is less common in southern James Bay. It breeds there and across southern Canada east of central British Columbia, generally in colonies and often with other gulls or terns. The species was first recorded at Churchill in 1968, and is now a common visitor with flocks frequently numbering 50-100 birds as the species' population and range expands (MARC 2003). The little gull and mew gull are rare in Hudson and James bays but do breed at Churchill (McRae 1984). The former is a European immigrant that breeds locally along the Hudson Bay coast at Churchill and Winisk and along the Great Lakes and St. Lawrence River. The latter breeds mainly in western Canada and is common along the British Columbia coast. Another European species, the lesser black-backed gull, has been observed at Churchill but is not known to breed in Canada. Laughing gull, Franklin's gull, and black-headed gull are rare accidental summer visitors to Churchill (MARC 2003). None of these species is known to overwinter in the region.

The black-legged kittiwake also occurs on the open waters of northern Hudson Bay in July and August, and occasionally at Churchill in early summer (Brown et al. 1975; Brown 1986; MARC 2003). It is not known to breed in the region.

Arctic, common, black, and Caspian terns are seasonal visitors to Hudson and/or James bays. Two other species, Forster's tern and white-winged tern, are rare accidental summer visitors to the Churchill area (MARC 2003). The former frequents primarily freshwater marshes, and the latter is a Eurasian marsh bird.

The Arctic tern breeds in suitable areas all along the coastline, and across northern Canada. It usually nests in colonies on islands or protected sand spits, in the vicinity of salt or fresh water where it can forage for food. The species is less common along the low-lying western coast of James Bay, which has few suitable breeding sites. Tern colonies are very common in the Long Island area of southeastern Hudson Bay (Nakashima and Murray 1988), and there was a colony of 10,000 in the Fox Islands (58°47'44"N, 93°34'57") near Churchill in 1930 (Taverner and Sutton 1934). Arctic terns fora[illegible] in ice leads when they arrive from the south in mid-May (Jehl and Smith 1970; Evans and McNicholl 1972). They return south in late August and early September along the Atlantic or Pacific coasts to winter in the southern hemisphere, and are rarely seen in the Canadian interior. The number of Arctic terns nesting in the Belcher Islands declined between 1985-88 and 1997 (Gilchrist and Robertson 1999). The causes of these declines are unknown but might be related to egg gathering by Inuit from Sanikiluaq.

The common tern breeds on the islands and coasts of southern James Bay. It is distributed north to Comb Island along the eastern coast and occasionally visits Churchill. The species is common throughout much of southern Canada. The black tern also breeds locally along the southern and western coasts of James Bay from Attawapiskat River south to Moosonee, and occurs on North Twin Island. It is rare at Churchill where breeding was reported on the Fox Islands near Churchill in 1932 (Taverner and Sutton 1934). This report has since been questioned (MARC 2003). Both species primarily frequent freshwater.

The Caspian tern is an occasional summer visitor, near the northern edge of its range, along the Ontario and Manitoba coasts (see also Jehl and Smith 1970). It may breed on Akimiski Island, at the mouth of the Attawapiskat River, and near Winisk (Cadman et al. 1987). Like the Arctic tern, the Caspian tern will forage in coastal waters.

10.17 F. ALCIDAE: Auks, Murres, and Puffins

Birds of this family are excellent swimmers and divers. They eat a variety of marine fishes and invertebrates and come ashore only to breed. There are breeding colonies of black guillemots, thick-billed murres, razorbills (*Alca torda*), and Atlantic puffins (*Fratercula arctica*) on cliffs at the extreme northeastern corner of Hudson Bay, just north of the Hudson Bay marine ecosystem (Gaston et al. 1985, 1993; Cairns 1987a+b; Cairns and Schneider 1990; Gaston and Donaldson 1995; Donaldson et al. 1997; Chapdelaine et al. 2001; Gaston 2002). The black guillemot has a wider breeding distribution in the region and the dovekie occurs but is not known to breed. The razorbill winters from southern Labarador southward to the Canary Islands, but the other species winter in the breeding range where open water permits and are rare in south central and western Canada. They all breed primarily along the Atlantic coast.

The black guillemot nests in small colonies on steep shores at Cape Henrietta Maria, along the Quebec coast from Chisasibi northward; on the Twin Islands, the Belchers, and other islands in southeastern Hudson Bay; on Southampton and Coats islands; and along the Kivalliq coast south to at least Rankin Inlet (see also East 1938; Manning and Coates 1952; MARC 2003). It is one of the most abundant and characteristic seabirds along the coasts of Hudson and James bays and on the outer islands almost to the head of James Bay. Most of the lowland coastal habitat is unsuitable for black guillemot breeding, since the species prefers to lay its eggs on bare rock or loose pebbles. The black guillemot is a year-round resident of the Belcher Islands area, and also winters in leads offshore Churchill (MARC 2003).

The thick-billed murre is uncommon but has been reported at the Belcher and Nastapoka islands in summer. Large breeding colonies of these birds are located north of the Hudson Bay marine ecosystem on northern Coats Island (30,000 breeding pairs in 1990; Gaston et al. 1993) and in the Digges Sound area (300,000 breeding pairs in 1980; Gaston et al. 1985). Birds tagged at these colonies have been recovered mostly along the Newfoundland coast, but some are taken in Greenland or by local communities (Donaldson et al. 1997). Inuit report that the species winters in large numbers in areas of open water west of the Belchers. Inuit harvest guillemots and murres along the Quebec coast (JBNQNHRC 1988) and in the Belcher Islands (J. Pattimore, Iqaluit, pers. comm. 1986), and murres in the Repulse Bay area (Gamble 1988)(see Section 14.6).

The dovekie is not known to breed along the Hudson Bay or James Bay coasts but occurs commonly as a migrant, winter resident or summer non-breeder along the coasts of northern Hudson Bay (Brown et al. 1975). It has been reported in winter at Kuujjuarapik and Eastmain, where it may have been transported from the Atlantic coast accidentally by storms.

Three other Alcids, the common murre (*Uria aalge*), razorbill, and Atlantic puffin have been observed on rare occasions just outside the ecosystem boundaries at the north end of Coats Island (Gaston and Ouellet 1997) and, in the case of the latter two species, in the Digges Sound area (Gaston et al. 1985).

10.18 F. STRIGIDAE: Typical Owls

The Strigidae include all the owls except the barn-owls. The snowy owl and the short-eared owl breed and forage along the coasts of Hudson Bay and James Bay.

The snowy owl is one of the few birds that remain in the region year-round; unlike most other owls it is active in daylight--a necessity during the Arctic summer. The species' breeding distribution includes coastal habitats north of Inukjuak on the east side of Hudson Bay, north of Churchill on the west side, on Southampton, Coats and Mansel islands, and on the Belchers. While widespread, the snowy owl is not numerous--particularly in the south in summer. It nests on hummocky tundra and can sometimes be seen perched on a rock or knoll overlooking a coastal beach or tidal flat while hunting shorebirds, geese, ptarmigan, or lemming (Moser and Rusch 1988). During winters when lemmings are scarce, about every four years, the snowy owl migrates southward to find food. In the Belcher Islands, owls prey on eider ducks and are associated with large groups of eiders at polynyas in March (Gilchrist and Robertson 2000). They follow the eiders, which are responding to changing ice conditions, and take them when they are loitering on ice edges at night. Snowy owls will also take oldsquaw ducks directly from the water. Inuit occasionally harvest the snowy owl for food (JBNQNHRC 1988).

The short-eared owl is a seasonal visitor that breeds along the coasts of James Bay and Hudson Bay north to north of Richmond Gulf in the east and Chesterfield Inlet in the west. It is a medium-sized, buffy-white owl that can sometimes be seen over the ocean (Lewis and Peters 1941), or hunting in salt marshes. Like the snowy owl, it is active during the day but it is most active in the evening. The species is present at Churchill from late April to early November (MARC 2003). It has been designated species of "Special Concern" by COSEWIC. The main cause of concern is an important and well-documented decline in the past resulting from the loss of its preferred habitat due to agricultural development in the south ([illegible]).

10.19 F. ALCEDINIDAE: Kingfishers

The belted kingfisher breeds along the James Bay coast, and along the Hudson Bay coasts north to Kuujjuarapik in the east and Churchill in the west (Lane and Chartier 1983; Cadman et al. 1987). They may occasionally forage in coastal waters and estuaries.

10.20 F. CORVIDAE: Jays, Magpies, and Crows

The American crow and common raven scavenge along the coasts of Hudson and James bays. The American crow breeds along the south coast of Hudson Bay from Cape Henrietta Maria to Churchill and along the southern and western coasts of James Bay. It winters in southern Canada. The common raven breeds along the coasts of Hudson and James bays, except perhaps on Coats and Mansel islands. Nest sites are often located on cliffs or in trees, near garbage dumps, or seabird colonies. Whimbrel eggs make up a substantial portion of the species' diet in June and early July at Churchill (Jehl and Smith 1970). The common raven is one of the few species that winters in the region--often in coastal areas. Ravens have been observed along landfast ice edges around the Belcher Islands, in March, eating the remains of seals killed by Inuit or polar bears (Gilchrist and Robertson 2000).

10.21 F. ALAUDIDAE: Larks

The horned lark arrives in late April and departs by mid-October. It is a common summer breeder on treeless raised marine beach ridges along the Hudson Bay and James Bay coast. A favorite feeding place for the horned lark is at piles of kelp along the shore (Manning 1981). The species' abundance as a breeder on the coastal beaches makes it of interest to visitors. It breeds widely in Canada and winters in southern Canada and throughout the United States.

10.22 F. MOTACILLIDAE: Pipits

The American pipit is common along the shores of Hudson and James bays. The species generally arrives from the south in late May and departs from northern areas in mid- to late August. It breeds along the Quebec coast north of Paint Hills Bay, on the west coast of Hudson Bay from Cape Henrietta Maria north, on the small islands of James Bay north of Gasket and Weston Islands, and on the islands in Hudson Bay--except perhaps on Mansel Island. It is very common in southern James Bay during the fall southward migration in September. The American pipit nests on vegetated, usually sloping, rocky ground and frequents coastal shores, beaches, and mud flats during migration. The species breeds from the southern Barrens north to the middle Arctic, and in British Columbia and Newfoundland in southern Canada. It is a common spring and fall migrant throughout southern Canada.

10.23 SUMMARY

The Hudson Bay marine ecosystem provides resources of critical importance to migratory waterfowl and shorebirds. Hudson Bay has the effect of funnelling southward migrating species of Arctic shorebirds and waterfowl into James Bay. With its rich coastal marshes, wide tidal flats, and extensive eelgrass beds, James Bay is one of the most important stopping places in North America for migrating Arctic-breeding shorebirds and waterfowl. It is matched only by the Copper River delta and Bristol Bay in Alaska and, for shorebirds, by the upper Bay of Fundy. These birds, particularly the geese and ducks, have sustained, and continue to sustain, important subsistence harvests by Inuit and Cree (see Section 14.6). Despite the long history of research, there are a number of gaps in our knowledge of this region's bird fauna. Most studies have examined coastal areas during spring, summer, and/or fall. We do not know to what extent birds use offshore waters, overwinter in open water areas, or even what bird species inhabit long stretches of coastline.

At least 133 species of swimming birds, shorebirds, raptors, and scavengers frequent offshore, inshore, intertidal, or salt marsh habitats of the Hudson Bay marine ecosystem. The area provides coastal breeding habitat for at least 102 species, including many that are primarily Arctic breeders--some of which are rarely seen in breeding condition outside the Arctic Islands. It also provides vitally important feeding, staging, and/or moulting habitats for many resident and transient species.

Because of their geographical location and transitional character, James Bay and southern Hudson Bay support some of the most southerly examples of Arctic-breeding species, and some of the most northerly examples of southern-breeding species--both of which offer interesting opportunities for study. Despite a rich avifauna most species are common and numerous elsewhere in Canada--the Hudson Bay eider is a notable exception.

The distribution of birds in the ecosystem is determined largely by habitat availability and climatic factors, particularly temperature. Wide differences in coastal habitats and climates mean that species common in one area may be uncommon or absent in another. Low-lying rocky islands, wide tidal flats--often associated with wet lowland tundra, salt marshes, eelgrass beds, coastal cliffs, and open water (e.g., polynyas) are particularly important habitat. Biological oceanography is also important as it determines the local abundance of food for nearshore and offshore feeders.

Tidal flats in western James Bay, particularly north and south of the Albany River, provide resources of critical international importance for migrating Hudsonian godwit and red knot. In the fall, the knots and numerous other species of shorebirds make a direct flight from James Bay to the Atlantic seaboard or, in the case of Hudsonian godwit, to South America. They require fat built up from feeding along the James Bay coast to fuel them on the flight. During breeding season most of these shorebirds frequent coastal areas that have moist to wet vegetated tundra and sometimes salt marshes or higher, drier areas with low vegetation.

The islands and coasts of James Bay offer breeding, feeding, and/or moulting habitat to a wide variety of species, many of them near the limits of their breeding distributions. Akimiski Island in western James Bay supports the most southerly breeding colonies of lesser snow goose, Ross's goose, and oldsquaw; the Twin Islands in Eastern James Bay also support a variety of typically Arctic-breeding species. Way Rock in eastern James Bay supports perhaps the only breeding colony of the double crested cormorant on Canada's Arctic coast, and the American bittern is an unusually common breeder in the marshes of western James Bay.

Large areas of the Hudson Bay and James Bay coasts provide critically important habitat for migrating and moulting North American waterfowl. Waterfowl are also very important to the regional economy, both for subsistence and to attract sport hunters. Some species are colonial and can be very numerous in suitable habitats. At least 28 Anatid species breed along the coasts and frequent coastal marine habitats in summer, and a few overwinter. During the breeding season most of these waterfowl frequent low-lying, sometimes hummocky, moist to wet vegetated tundra near lakes or coastal river mouths. The eiders are exceptions and often nest on low-lying rocky coasts and islands, especially where mussel beds and reefs provide feeding grounds. After the young hatch they often congregate in flocks along the coasts.

The Canada goose breeds in large numbers, though at low densities, in inland marshy areas. It is a numerous spring and fall transient, particularly along the James Bay coasts. In the Belchers and on Akimiski Island, these geese make extensive use of saline habitats. They are characterized by very large salt glands, which develop to cope with the high salt intake. Many of the individuals marked at nesting areas in western James Bay winter in the Mississippi Valley, while those from the Belchers and the Quebec coast winter mainly along the Atlantic coast. Geese from Akimiski Island and southern James Bay apparently winter in the Tennessee Valley. Inuit and Cree have observed changes in the migratory patterns of both Canada and snow geese in Hudson Bay and James Bay.

The lesser snow goose breeds mainly in the Arctic and along the coasts of Hudson Bay. Its most southerly large breeding colony in Canada is located at Cape Henrietta Maria, and there is also a small breeding colony on Akimiski Island. During migration, the entire Foxe Basin population of over a million birds stops to rest and feed at marshes on the west coast of James Bay. The region supports over 50% of the eastern Arctic breeding population of the lesser snow goose, *Chen caerulescens caerulescens* Linnaeus, which has increased significantly in the past 30 years. Breeding colonies are dotted along the Hudson Bay coast and the species is locally very numerous, so much so that overgrazing is degrading their prime habitats at La Pérouse Bay, in the McConnell River Migratory Bird Sanctuary, and elsewhere (see Section 6.5).

Rich and extensive beds of eelgrass along the northeast coast of James Bay provide food resources of critical North American importance to brant (see Section 6.4). The brant is a saltwater species that breeds in the Arctic and on Southampton Island, and is seldom seen in much of southern Canada. These geese graze extensively on beds of eelgrass along the coasts of James Bay in spring and fall (late September-early November). During the fall migration over 50% of the Atlantic brant population may use these habitats. The area of critical habitat south of Roggan River is nationally important, because of the extensive eelgrass beds which attract up to 20,000 brant, and also many thousands of Canada Geese, and numerous ducks--principally black duck, in the fall. Many thousands of brant pass through southern James Bay (e.g., Netitishi Point) on their way south in late fall. They follow a relatively narrow migration corridor through Quebec enroute to and from their wintering grounds along the Atlantic coast of the United States.

The Hudson Bay subspecies of the common eider, *Somateria mollissima sedentaria* Snyder, is unusual in that it lives year round in Hudson Bay and James Bay. It breeds locally and commonly (colonial) along low-lying, tundra or rocky coasts throughout this region, and feeds almost exclusively on the blue mussel (*Mytilus edulis*). In the mid-1980s the breeding population in eastern Hudson Bay was estimated at 83,000 birds. These birds winter where open water and shallow depth coincide. Inuit report their presence, sometimes in quantity, at almost every ice edge that is accessible from Sanikiluaq in winter, and in a number of polynyas. In the winter of 1991-92, many eiders were found frozen into areas where the water usually remains open in winter. Inuit attributed these kills to decreases in the area's winter currents. Subsequent scientific studies estimated that the number of eiders nesting in the region declined by 75% between 1985-88 and 1997.

Two seabirds, the black guillemot and thick-billed murre, are harvested for subsistence. The black guillemot nests in small colonies on steep shores at Cape Henrietta Maria, along the Quebec coast from Chisasibi northward; on the Twin Islands, the Belchers, and other islands in southeastern Hudson Bay; on Southampton and Coats islands; and along the Kivalliq coast north of Chesterfield Inlet. It is one of the most abundant and characteristic seabirds along the coasts of Hudson and James bays and on the outer islands almost to the head of James Bay. Most of the lowland coastal habitat is unsuitable for black guillemot breeding, since the species prefers to lay its eggs on bare rock or loose pebbles. The black guillemot is a year-round resident of the Belcher Islands area. There are breeding colonies of thick-billed murres on cliffs in northeastern Hudson Bay. The species is uncommon but has been reported at the Belcher and Nastapoka islands in summer. Inuit report that murres winter in large numbers in areas of open water west of the Belchers.

A relatively dense, productive population of peregrine falcons nests on cliffs and islands along the Kivalliq coast near Rankin Inlet. The birds arrive on the breeding grounds in mid-May from wintering areas as far south as Uruguay. Nests are situated on cliff ledges, often near seabird colonies. Peregrines inhabiting coastal areas in summer prey on shorebirds, seabirds, and small mammals, which they kill with a blow from their feet following a spectacular dive. The population has relatively low pesticide residues and high reproductive success, but there is still measurable pesticide-related egg thinning. In 2003, there were 25 active nests and 26 young were fledged. The area has one of the highest and best-known concentrations of peregrines in the world and should be considered for protection. COSEWIC considers the subspecies to be of "Special Concern".

Ross's and ivory gulls are rare spring visitors to Hudson Bay and James Bay. The Ross's gull will nest at Churchill and occurs in summer at the McConnell River in Kivalliq. The species usually nests in the Canadian high Arctic and in Siberia, may overwinter at Arctic polynyas, and is rare in southern Canada. It has been designated as "Threatened" by COSEWIC. The ivory gull may occur more widely and in both summer and winter, but breeds further north. It has been designated a species of "Special Concern" by COSEWIC. The short-eared owl and yellow rail have also been designated species of "Special Concern" by COSEWIC.

The coastal wetland habitats are protected by a number of migratory bird sanctuaries and National and Provincial Parks (see Chapter 12). The Moose River, Hannah Bay, and McConnell River migratory bird sanctuaries, and Polar Bear Provincial Park, have been designated as Ramsar sites under the Convention on Wetlands of International Importance as Waterfowl Habitat (The Ramsar Convention). However, the areas of greatest value to shorebirds, north and south of the Albany River in James Bay, have not yet been afforded statutory protection. Fortunately, they are not under any immediate threat. The Canadian Wildlife Service considers the Sleeper, North Belcher, and Salikuit islands to be sensitive habitats on account of their large indigenous populations of Hudson Bay eider.

11.0 HUMAN OCCUPATION

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Table 11-3. Coastal settlement of Hudson Bay and James Bay 11–15

There is a relatively short record of human occupation along the coasts of Hudson and James bays. If this region was occupied during early interglacial periods, then the last (Wisconsin) glaciation certainly eradicated all traces. Its prehistoric occupation apparently began about 4000 years ago, not long after the last glaciers melted. Archaeologically, the prehistory of Eskimo peoples who lived north of the treeline is better known than that of the northern Indian peoples--perhaps because sites of occupation are relatively exposed on the barrens. Because of post-glacial isostatic rebound much of the prehistoric, coastal archaeological record is now situated at varying distances inland (Harp 1976; Plumet 1976). In North American terms, this region has a long history of European occupation, many aspects of which are well documented in the Hudson's Bay Company Archives in Winnipeg.

A number of comprehensive bibliographies are available for the area, including particularly Feit et al. (1972) on the Indians of James Bay, and Levesque (1988) on the social impacts of hydroelectric development in James Bay.

11.1 PREHISTORY (2000 BC-1610 AD)

The islands and coastal areas of Hudson Bay and the east coast of James Bay south to about Chisasibi were occupied prehistorically, mainly by Eskimo peoples (Jenness 1932; Figure 11-1). This region appears to have been marginal in Pre-Dorset, Dorset, and Thule periods, and climatic fluctuations may have played an important role in its suitability for coastally adapted Eskimo peoples (Fitzhugh 1976). The extent of coastal occupation by prehistoric Indians is not well known (Wright 1972, 1981; Chism 1976).

11.1.1 Pre-Dorset Culture (2000-800 BC)

The first Paleo-Eskimos to occupy the region's coasts crossed the Bering Strait from Siberia and spread rapidly across Arctic Canada, colonizing the eastern and western coasts of Hudson Bay about 2000 BC (Taylor 1968; Plumet 1976; McGhee 1978; Wright 1979). They lived in temporary settlements of tents and perhaps snowhouses, and used harpoons to hunt seals, walruses, and small whales. They also hunted a variety of land mammals and speared migrating Arctic charr at stone weirs (saputit). Oil lamps were used to provide heat and light, skin-covered boats may have been used to hunt marine mammals, and dogs may have been used for hunting or packing.

Pre-Dorset people are probably related biologically and culturally to the Inuit, but lacked technology that has allowed the more recent Inuit to adapt to Arctic conditions (McGhee 1978). They often inhabited the same sites as later cultures, and may have built the first fish weirs and caribou drive fences at these locations. The Pre-Dorset culture apparently occupied western Hudson Bay south to the Churchill area, and eastern Hudson Bay south to Grande rivière de la Baleine (Plumet 1976; Maxwell 1984, 1985; Figure 11-1). The Belcher Islands were mostly under water during the Pre-Dorset period and may have been uninhabited (Maxwell 1985). The culture appears to have become extinct about 800 BC in all but the marine mammal-rich areas of northern Hudson Bay, Hudson Strait, and Foxe Basin. This extinction may have resulted from changes in the availability of caribou and/or marine mammals related to a period of colder and unstable climatic conditions (Fitzhugh 1976).

11.1.2 Dorset Culture (800 BC-1500 AD)

Remnants of the Pre-Dorset culture gradually gave rise to the Dorset Culture between 800 BC and 500 BC (Taylor 1968; Fitzhugh 1976; Plumet 1976; McGee 1978; Wright 1979; Maxwell 1984, 1985). In early Dorset times southeastern Hudson Bay appears to have been unoccupied, except in the Belchers where ice conditions may have been more suitable (Maxwell 1985). The earliest Dorset sites on those islands, carbon dated between 780 and 500 BC, are elevated 55 m above the present sea level. Some coastal sites occupied by the Dorset Culture are shown in Figure 11-1.

The Dorset people had a more successful economy than the Pre-Dorsets, lived in more permanent houses built of snow and turf, and heated with soapstone lamps (Taylor 1968; Wright 1979; Maxwell 1984). They used hand-pulled sleds and possibly kayaks, but apparently lacked the skin floats that enabled later Inuit to harpoon larger marine mammals so effectively. The Dorsets lived primarily by hunting sea mammals and were capable of taking animals as large as walruses and narwhals, and possibly bowhead whales. They were displaced from most Arctic regions about 1000 AD by an invasion of Alaskan Eskimos but continued to live in northern Quebec and Labrador until about 1500 AD.

The east coast of Hudson Bay may have been a refuge for a terminal Dorset population (Harp 1976; Maxwell 1976, 1984). Some of the most recent Dorset sites, carbon-dated 1400 and 1440 AD respectively, are located near the entrance to Richmond Gulf (Lac Guillaume Delisle) on the northern tip of Belanger Island and the north shore of Gulf Hazard. Both sites were located near areas of year-round open water, and may have been outside the range of the earliest Thule migrants. The Dorsets at Gulf Hazard had either indirect or direct contact with Norse settlers, as evidenced by the discovery of a harpoon-shaped copper amulet of European origin in a Gulf Hazard Dorset house carbon-dated 1155 AD.

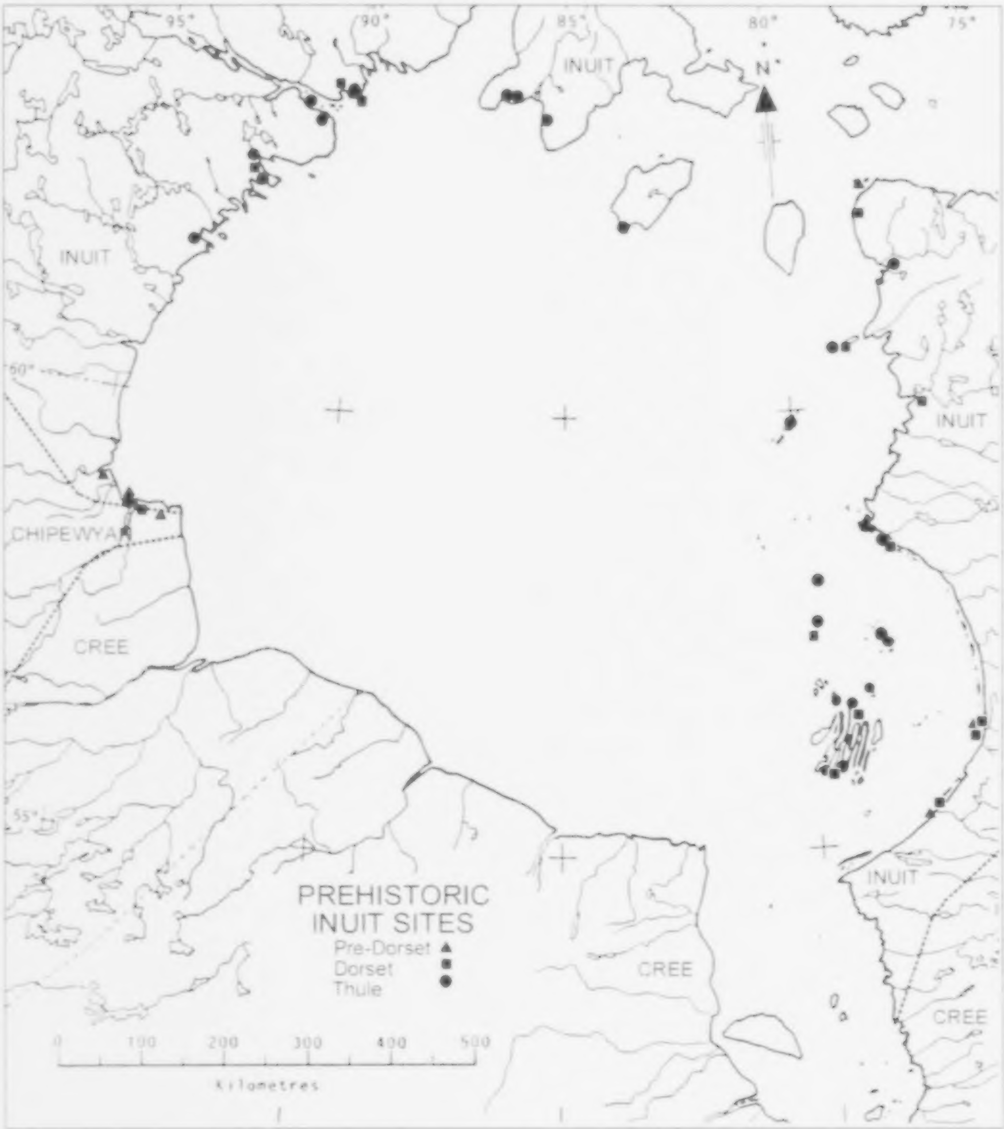

Figure 11-1. **Sites occupied by prehistoric Inuit cultures (after Inuit Land Use and Occupancy Project 1976, vol. 2, p. 117-122) and approximate boundaries of Inuit, Cree and Chipewyan cultures during the first two centuries of white contact (after Canada 1980).**

11.1.3 Thule Culture (1000-1600 AD)

Climatic warming about 1000 AD facilitated an expansion of Alaskan Eskimos across Arctic Canada, with development of the Thule culture and gradual displacement of the Dorset culture (Taylor 1968; McGee 1978; Wright 1979; Maxwell 1984). Thule people populated the Hudson Bay coasts about 1200-1300 AD (Harp 1976; McGee 1984). They brought with them a sophisticated sea hunting technology that had been developed in the Bering Sea area. It included float harpoons, kayaks, umiaks (large leather boats), dog sleds, and other useful innovations. They hunted animals as large as bowhead whales and were able to store sufficient food to allow winter occupation of permanent villages with houses built from stone, whalebones, and turf. Whales were stalked and chased in the open sea using an umiak and a small fleet of kayaks. Caribou were also hunted in the water from kayaks, using harpoons or bow and arrow. In winter, some Thule people probably lived in domed snow houses on the ice where they hunted seals.

Sites along the coasts of Hudson Bay that were occupied by the Thule Culture are depicted in Figure 11-1. Sentry Island (Arviatjuaq) near Arviat was first occupied about 1200 AD and has some 117 archaeological sites (Travel Keewatin 1990?). One site may be a beluga hunting/caribou crossing game. It consists of stone outlines of kayaks, shorelines, and other features, and the object was apparently to hone hunting skills. Hunters placed themselves inside the stone kayak outlines while someone pulled a rope with a small loop on the end from one end of the site to the other. If a hunter managed to get the point of his harpoon through the loop, he got a whale. Little is known of the Thule culture along the east coast of Hudson Bay. But, there appears to have been local specialization by Thules living in the Belchers (Quimby 1940; Jenness 1941; Benmouyal 1978). The relationship between these people and the historic occupants of the islands and adjacent coastal areas is unknown (McGee 1984).

The Thule economy declined with deteriorating climatic conditions after about 1600 AD but the people continued to occupy arctic Canada and are directly ancestral to the present Inuit (Taylor 1968; Wright 1979; McGee 1984; Maxwell 1985). In response to the colder environment, which may have prevented bowhead from reaching their Arctic feeding grounds, local groups adapted to survive on the resources of their areas. Life appears to have become poorer and less secure, as evidenced by a marked simplification in technology and a decrease in ornamentation applied to artifacts. The result was a series of local cultures, each with a slightly different dialect and way of life.

11.1.4 Inuit Culture (1600-present)

Four cultural groups, or regional bands, of Inuit occupied the coasts of Hudson Bay at the time of contact with the first Europeans (Damas 1968; McGhee 1978; Saladin d'Anglure 1984). In Nunavut, the Caribou Inuit lived on the Kivalliq barrens, the Sadlirmiut on Southampton Island and possibly on Coats Island, and the Aivilingmiut on the mainland north of Chesterfield Inlet. The Itivimiut lived along the Quebec coast from Cape Smith south to the entrance of James Bay and on the adjacent islands and interior barrens. The Caribou Inuit were devoted mostly to inland life, while the other groups had a mixed land-sea economy, comparable to that of the Netsilik and Copper Inuit, but with a greater emphasis on sea mammals. The seasonal cycles of these groups were closely related to local resource availability, and the relationships between groups were related to these cycles (e.g., Balikci 1964; Freeman 1964; Damas 1968; Schwartz 1976; Saladin d'Anglure 1984).

Each of these regional bands included several local bands whose members intermarried and shared linguistic and cultural characteristics (Arima 1984; Mary-Rousselière 1984; Saladin d'Anglure 1984). These local bands were often referred to by the generic name of an island or archipelago, for example the *arvilimmiut* of *arviliit* (Ottawa Islands); the *qumiutarmiut* of *qumiutait* (Sleeper Islands); the *qikirtamiut* of *qikirtait* "the islands" (Belcher Islands).

The Caribou Inuit concentrated on hunting caribou, particularly during the autumn migration, but also fished coastal rivers in spring and fall to catch migrating Arctic charr, and occasionally hunted seals and walruses at the coasts (Damas 1968; Arima 1984). The Sadlirmiut and southern Aivilingmiut hunted walrus at the floe edge and seals at breathing holes in winter, and seals on the ice in spring in their respective areas. In summer one group of Sadlirmiut went inland to hunt birds and catch fish while others hunted seals and walrus from kayaks. Caribou were hunted in September, and after freeze-up the Sadlirmiut moved from tent camps to permanent winter settlements, unlike the other groups. While the Aivilingmiut alternated hunting marine mammals on the ice and in the water with terrestrial hunting and fishing, more importance seems to have been given to caribou hunting (Mary-Rousselière 1984). Repulse Bay, Lyon Inlet, and Wager Bay--areas rich in walrus, caribou, and muskox, were their major centres of habitation. They lived in igloos in winter and skin tents in summer, and used kayaks.

The Itivimiut of coastal Quebec spent winter and much of the summer hunting seals and belugas (Damas 1968; Saladin d'Anglure 1984). Most of the Itivimiut lived in the coastal zone or on the islands, but there were small groups inhabiting the Quebec interior up until the 1930's (Saladin d'Anglure 1984). The Itivimiut were very mobile. Using an umiak, kayaks, and dogs a group of 20 to 30 people with weapons and baggage could travel several hundred kilometers along the coasts or major river courses in summer. The coastal and island Itivimiut either travelled inland periodically to hunt caribou and to fish, or traded with the inland Itivimiut. To obtain caribou skins and warm caribou clothing, the Islanders would trade the Inlanders ivory for making weapons and utensils, and bearded seal skins for making boot soles. They seldom ventured south of the treeline for fear of conflict with the Cree who inhabited the woodlands (Davies and Johnson 1965; Francis 1979). There appears to have been little cultural exchange between the Cree and Inuit (Preston 1981).

Seals, walrus, belugas, and polar bear were hunted for food and materials (Freeman 1964; Schwartz 1976; Saladin d'Anglure 1984). Bearded seals were in particular demand as their skins were used to make boot soles, straps, lines, and tent and boat covers. Lacking caribou, the Belcher Islanders would use other skins to make clothing and tents. Eider ducks skins were sewn together with thread made from dried seagull oesophagus to make winter clothing; the skins of bearded and ringed seals, belugas, and even fish were used to make tents. Stone fish weirs were used in the spring and fall to harvest Arctic charr, and waterfowl and seabirds and their eggs were also harvested in quantity. Mussels in the Inukjuak area, and sea urchins and sea cucumber in the Belchers, provided supplementary foods year-round, offering an appreciated dietary complement and an assurance against famine.

The offshore islands of southeastern Hudson Bay were a valued refuge when violent conflicts broke out on the mainland between Inuit and Indians or between Inuit groups (Saladin d'Anglure 1978, 1984). They were also important areas for the harvest of species such as walrus and polar bear, which were less accessible on the mainland. There were permanent Inuit populations on the Belcher Islands and smaller, less permanent groups on the Sleeper Islands. Both Indians and Inuit have wintered on Long Island and on many of the islands in James Bay (Schwartz 1976).

11.1.5 Indian Cultures

The extent of Indian occupation and exploitation of the James Bay and Hudson Bay coasts before European contact is not clear. Indians did visit the coast, as evidenced by their meetings with Hudson and other early European explorers, but they may not have lived there year-round until after the Hudson's Bay Company posts were established in the late 1600's (Trudeau 1968; Bishop 1981; Honigmann 1981; Wright 1981). Indeed, the Cree and Chipewyan Indians never developed the sophisticated marine hunting technology that enabled Inuit to thrive along the inhospitable coasts of northern and western Hudson Bay (Irving 1968; Wright 1972; Jenness 1932). Lacking seaworthy boats and harpoon technology, they hunted birds and land mammals and caught fish in the rivers. Many groups in the central Shield region shifted out of their aboriginal territories within the early contact period (Bishop 1981).

Historically, two groups of Algonquian-speaking peoples have occupied the region's coasts, the Swampy or West Main Cree along the western coast of James Bay and southern coast of Hudson Bay from the Hurricana River west to the Nelson River (Honigmann 1981), and the East Main Cree along the eastern coast of James Bay from the Nottaway River north to Richmond Gulf (Preston 1981) (Figure 11-1). Athapaskan-speaking people, the Chipewyan, ranged to the coast near Churchill between the Cree and the Inuit to the north (Jenness 1932).

Maritime harvesting apparently played a minor role in the lives of West Main Cree, who harvested large numbers of waterfowl, land mammals, and freshwater fish (Honigmann 1981). They did occasionally kill polar bear, seals or belugas for skins, oil, and dogfood. But, hunting walruses in fragile canoes was considered to be too dangerous (Johnson 1961).

The basic dwelling for both the East Main and West Main Cree was often a conical lodge supported by poles and covered by bark, skins, brush or, in winter, turf (Honigmann 1981; Preston 1981). Dome-shaped dwellings walled with bark sewn to a willow framework were also used along the south coast. During the open water the Indians hunted in small canoes and moved the family and possessions in larger craft, both were covered by birch or spruce bark, and were occasionally used to venture into salt water. Toboggans and snowshoes were used for winter transport, but dog traction was not introduced until the mid-1700s.

Maritime resources played a somewhat greater role in the lives of the East Main Cree, but it was still minor relative to the Inuit (Preston 1981). There were two main groups of Eastmain Cree. The Coasters or 'salt-water people' occupied the coastal lowlands and islands year-round, while the Inlanders traditionally lived inland but traded at the coastal posts. The Coaster-Inlander distinction is most pronounced in the north, where maritime efforts, particularly sealing, are most important--Twentieth century Cree regard them as "the same" people who get their living under different circumstances. It is not known whether this coastal occupation is ancestral in origin or an artifact of the fur trade. The Coasters historically got their living by hunting, fishing, fowling, and gathering, with maritime efforts, especially sealing, increasing in importance moving northward. Seals, belugas, and polar bears were among their maritime prey.

The East Main Coasters appear to have had stronger ties to the Inlanders than to West Main Cree who lived along the coasts (Preston 1981). For practical and congenial reasons, Coaster families would accompany an Inlander family if they wanted to spend a season inland, and vice-versa. Coasters and Inlanders would gather for feasts and games. East Main and West Main Cree who lived along the coasts tended to be more closely associated with the trading posts than their inland relatives who visited mainly to trade (Honigmann 1981; Preston 1981).

Cree-Inuit relations occasionally were violent in the past, particularly in the 1700's when West Main Cree would undertake raids on the Inuit of southeastern Hudson Bay, massacring adults and capturing children (Davies and Johnson 1965; Francis 1979). If they failed to find Inuit, the West Main Cree would sometimes attack East Main Cree. When these raids began to interfere with trade, the HBC took steps to promote peaceful co-existence between the Indians and Inuit. East Main Cree narratives trace a period of occasional but violent conflict with the Inuit, which led to a peace parley and to continuing amicable relationships (Preston 1981). There appears to have been little cultural exchange between the two, and close contacts seem to have amounted to individual friendships and rather rare intermarriage.

11.2 HISTORY (1610-2004 AD)

There have been four general phases in the history of the Hudson Bay and James Bay marine regions: 1) early exploration and mapping associated with the search for a Northwest Passage (1610-1632), 2) struggle for control of the bay and early fur trade (1668-1713), 3) development by the Hudson Bay Company and commercial whaling for bowhead (1714-1903), and 4) modern settlement (1903-present). During phase 1, there was little contact between aboriginal peoples and European explorers; phase 2 saw the beginnings of trade; phase 3 was characterized by widespread fur trade and participation in the whaling industry; and the most recent phase has seen increasing contact with traders, missionaries, and police, and the concentration of aboriginal peoples in coastal settlements.

Changing nomenclature presents a real difficulty in following historical accounts of this region. The difficulties of early mapping, the closure and re-establishment of trading posts, and the involvement of four languages compound this difficulty. Table 11-1 is an attempt to cross-reference some of the community names used in historical documents with those now in use.

Table 11-1. **Community or post names used in text and some of their equivalents in other languages. Communities are listed alphabetically by official geographical name (BOLD) (Canada Gazetteer). Old or lesser-used names are in brackets (see Fraser 1968; Honigmann 1984;** http://www.ottertooth.com/**; HBC Archives Post Descriptions).**

English	French	Inuit	Cree[1]
Cape Smith		**AKULIVIK**	
Eskimo Point		**ARVIAT**	
			ATTAWAPISKAT
BAKER LAKE		Qamanit'uaq	
BAKER LAKE NARROWS			
BIG HIPS ISLAND, (Willow Island)		Orpiktujok	
BURY COVE			
CHESTERFIELD INLET		Igluligaajuk	
			CHICHEWAN
Fort George, (Old River), (Big River), (Great River)	La Grande Rivière	Mailasi	**CHISASIBI** (Keeshay)
CHURCHILL			
COATS ISLAND			
CORAL HARBOUR		Salliq	
EASTMAIN, (Slude Fort)	rivière Slude ou Main		
FORT ALBANY, (Albany), (Albany Factory)	Ft. Ste. Anne		
FULLERTON HARBOUR			
Port Harrison		**INUKJUAK** (Inoucdjouac), (Inujjuaq), (Inuksuak)	
Wolstenholme		**IVUJIVIK**, (Ivugivik)	
			KASCHECHEWAN
			KUPISKAU
Great Whale River (Great Whale), (Big Whale River), (Whale River House)	Poste-de-la-Baleine (Baie de la Poste)	**KUUJJUARAPIK**	Whapmagoostiu (Wa-pim-ma-koos-too)
LAKE RIVER			
MAGUSE RIVER			
MANSEL ISLAND			
MOOSE FACTORY (Moose Fort), (Moose River)	Ft. St. Louis		Moosu Wiskihagan
			MOOSONEE
			PEAWANUK
		PUVIRNITUQ (Povungnituq)	
RANKIN INLET		Kangiqiniq	
REPULSE BAY		Naujat	
RICHMOND GULF (Fort Richmond), (Richmond Fort)			
Belcher Island, (Eskimo Harbour)		**SANIKILUAQ**	
		UMIUJAQ	
Old Factory (Factory River)	**VIEUX COMPTOIR**		
WAGER BAY			
Rupert House (Rupert's House), (Charles Fort), (Fort Rupert), (Ruperts River)	Ft. de la rivière Rupert		**WASKAGANISH**
Paint Hills (New Factory), (Big River)	Nouveaux Comptoir		**WEMINDJI**
WHALE COVE		Tikirarjuaq	

[1] The actual Cree word(s)--or in the case of Moosonee perhaps Ojibway, from which these anglicized names have been derived are often unclear (see Honigmann 1984; HBC Archives Post Histories).

11.2.1 Early Exploration and Mapping (1610-1632)

The early European explorers of Hudson Bay were commercially motivated. They sought an ice-free Northwest Passage that would shorten the route to the lucrative trade markets of the Orient (Rich 1958; Neatby 1968; Williams 1970; Newman 1985). Henry Hudson, in 1610, was the first navigator to leave a record of his entry into Hudson Bay and James Bay (Figure 11-2; Table 11-2). Vikings or fishermen may have preceded him, but they left no records of their visits. The unfortunate Hudson wintered in southern James Bay at the site where Rupert House (Waskaganish) was later built. While there he bartered a few trinkets for skins with a lone Indian. When his crew mutinied in the spring of 1611, Hudson, his young son and a few loyal crewmen were set adrift in a boat off Charlton Island. They may have visited Danby Island and reached Hudson Strait before perishing (Newman 1985, p. 35). The mutineers carried Hudson's map to England.

The discovery of Hudson Bay prompted further explorations, but James Bay was not re-visited until 1631, when Thomas James and his crew wintered at Charlton Island (Helfrich 1972; Kenyon 1975, 1986; Figure 11-2; Table 11-2). They returned to England after a miserable voyage and a worse winter, without contacting a single Indian or Inuit. James was convinced that there was no Northwest Passage via Hudson Bay, and that a more northerly passage was unlikely and in any event would be ice jammed and without commercial value. With this latest report, commercial interest waned and there were few European voyages to this region over the next 30 years.

11.2.2 Struggle for Control of the Bay (1668-1713)

Interest in the fur trade and recognition that Hudson and James bays might offer easy access to the fur-rich interior of North America generated a second flurry of commercially motivated exploration (Rich 1958; Neatby 1968; Williams 1970; Newman 1985). It began with the successful voyage of the Nonsuch to James Bay in 1668. A syndicate recruited by Prince Rupert to explore the fur trade potential of Hudson Bay sponsored the expedition under Captain Zachariah Gillam with the trader Chouart Sieur Des Groseilliers aboard. It landed at Rupert Bay, and wintered in a small stockaded house built near the mouth of the Rupert River. That spring nearly three hundred Indians came to trade, exchanging beaver skins--one of the most common commodities in the New World, for the "rare and useful" items brought by the Europeans. The expedition's successful return to England in August proved that it was practical to sail into Hudson Bay, winter on its shores, and return with a profitable cargo of fur. It led to the formation of the Hudson's Bay Company (HBC) in 1670, and soon ships were travelling to the bay every year to trade for furs.

The first establishments in James Bay were trading posts built by the HBC at the mouths of the Rupert (1668), Moose (1673), and Albany (1674) rivers, and a depot at Charlton Island (1681)(Figure 11-3; Table 11-1; see also Kenyon 1986). Among the French there was growing concern that these posts posed a direct and serious threat to the economy of New France.

Open hostilities between the HBC and the French began in 1682 at the mouth of the Nelson River in Hudson Bay (Rich 1958; Mathews 1966; Neatby 1968; Newman 1985; Kenyon 1986). The first trading posts along the Hudson Bay coast, including the HBC's Fort Nelson, Britain's Bachelor's Fort, and France's Fort Bourbon were built near the mouth of the Nelson River in 1682 (Figure 11-3). The French, under Radisson, soon burnt their rival's forts and imprisoned their competitors. In 1684, the HBC built a new post at York Factory and, in 1685, another at Severn. The James Bay posts were not attacked until 1686, when Pierre de Troyes travelled from New France with 107 men and overwhelmed Moose Factory, Rupert House, and Fort Albany in quick succession--leaving the French in control of James Bay. Rivalry between the French and English was intense and many of the posts in James Bay and Hudson Bay changed hands several times over the decade. It was 1692 before James Knight recaptured the James Bay posts, occupying Albany and burning the others to the ground to keep them out of French hands. The conflicts culminated in 1697 with a pitched sea battle near the mouth of the Nelson River in which a lone French man-of-war, Pelican under d'Iberville, sank the H.M.S. Hampshire and the Hudson Bay. The badly damaged Pelican was blown ashore by a squall after the battle but reinforcements arrived soon after and d'Iberville captured York Factory. In 1709 the French mounted their final attack on Albany, but were repulsed by the HBC who were determined to keep their last remaining Hudson-James Bay post in operation. Unlike the struggle for Hudson Bay, there were no pitched sea battles in James Bay. Signing of the Treaty of Utrecht in 1713, wherein France relinquished all claims to Hudson-James Bay marked the end of the conflict and the beginning of empire building by the HBC.

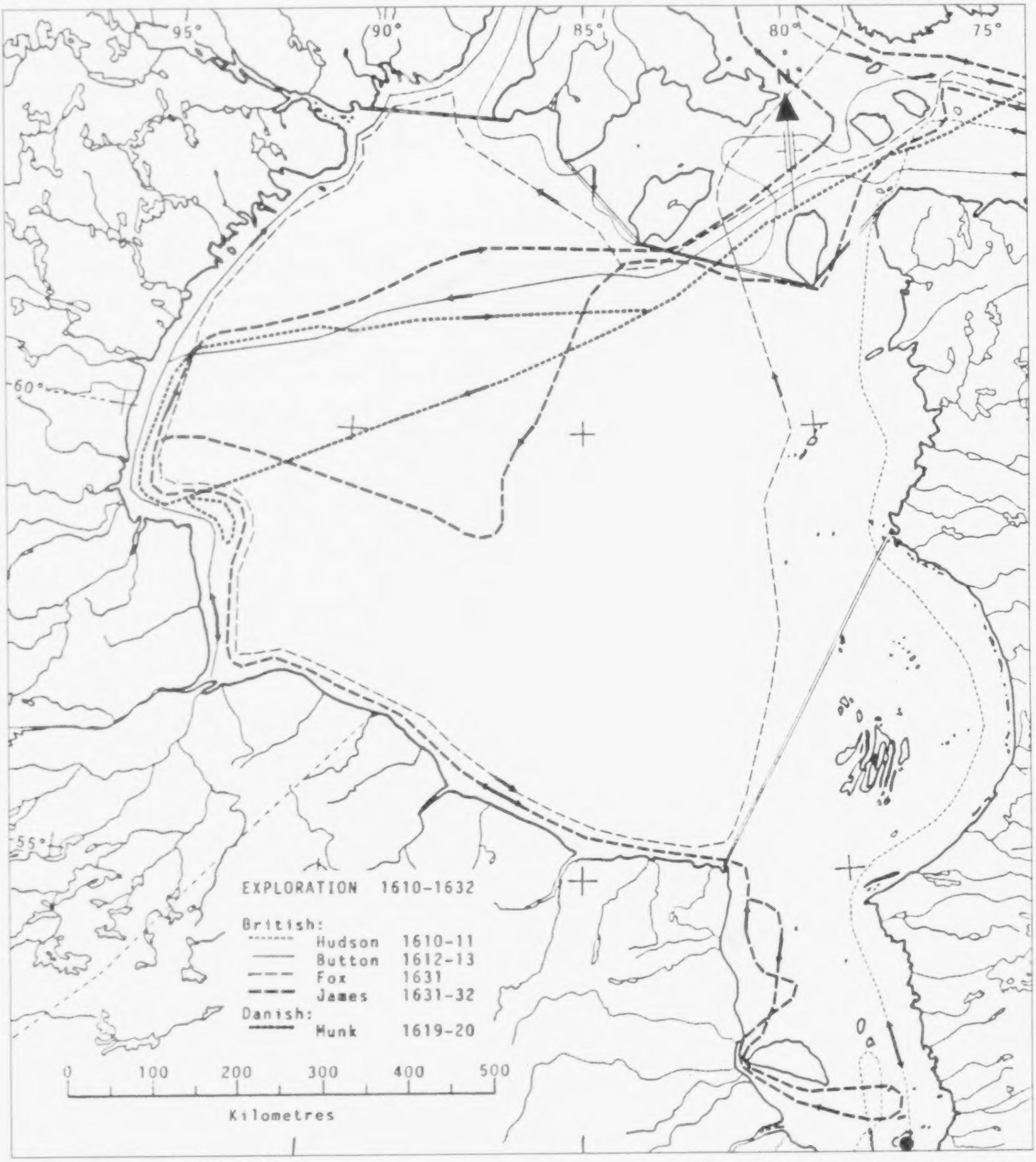

Figure 11-2. **European exploration of Hudson Bay and James Bay 1610-1632 (after Canada 1974). Solid dot marks Charlton Island where his crew abandoned Hudson.**

Table 11-2. Early European exploration of Hudson Bay and James Bay. Recent reprints of the original journals are cited where possible. See also Rich (1958) and Newman (1985).

Date	Principal Explorer	Ship and Nationality	Objectives and accomplishments	References
1610-11	HUDSON, Henry	Discovery, British	Sponsored privately by Smith, Digges, and Wolstenholme to search for a Northwest Passage. Entered Hudson Bay 21 July 1610, proceeded down east coast and wintered in Rupert Bay. On sailing again in June crew mutinied and Hudson and others were set adrift in a boat. Hudson was never heard from again, but the mutineers carried his map of the east coast to England.	Purchas (1613).
1612-13	BUTTON, Thomas	Discovery and Resolution, British	Sponsored privately by Smith, Digges, and Wolstenholme to search for a Northwest Passage. Discovered Coats Island and reached the west coast of the Bay at 60°40'N. Sailed south and wintered at Port Nelson. Sailed north in June 1613 to about 65°N in Roes Welcome, and discovered Mansel Island on the way home.	Foxe (1685).
1619-20	MUNK, Jens	Unicorn and Lamprey, Danish	Sent out by Danish King to search for Northwest Passage. Reaching the west coast at 63°20'N, he turned south and, caught by a very early winter harboured in Churchill River. Here 60 of his men died of scurvy and trichinellosis. Munk and 2 other survivors sailed home.	Munk (1624), Hansen (1970).
1631	FOXE, Luke	Charles, British	Outfitted a vessel to search for the Northwest Passage with Royal approval and London Merchant's backing. Crossed to the west coast of the Bay at Roes Welcome, then coasted south meeting and passing James southeast of Port Nelson on 29 August. Turned north and discovered the SW corner of Baffin Island on his way home.	Foxe (1685).
1631-32	JAMES, Thomas	Maria, British	Outfitted by Bristol merchants in rivalry with Capt. Luke Foxe (1685). Sailed SW into Hudson Bay and travelled along the south coast, wintering miserably at Charlton Island in James Bay. Sailed again 2 July 1632, roughly retracing his route on the way home.	James (1633), Kenyon (1975).
1741	MIDDLETON, C.	H.M.S Furnace and Discovery, British	Sent out by the British Admiralty to search for a passage at the northwest angle of Hudson Bay. Wintered at Churchill in 1741 and then traveled up the west coast of Hudson Bay, entering Wager and Repulse bays before being turned back by ice in Frozen Strait and returning home.	Middleton (1743), Dobbs (1744).
1744	MITCHELL, Thomas	Eastmain and Phoenix, British	Sent north from Moose Factory by the Hudson's Bay Company to explore the east coast of James Bay and southeastern Hudson Bay north to 60°N with a view to opening up trade. Charted the entrances of the Eastmain, Great Whale and Little Whale rivers, and entered and mapped Richmond Gulf.	Williams (1963), see also Eastmain sloop journal in HBC Archives.
1749	COATS, William	Mary and Success, British	Sent from England by the HBC to explore the eastern coast of Hudson Bay from Cape Digges to Richmond Gulf in search of a safe harbour where a trading post could be established. Entered and mapped Richmond Gulf and recommended the establishment there of Richmond Fort.	Williams (1963).
1761-2	CHRISTOPHER, William	Churchill and Strivewell British	Sent by the Hudson Bay Company to determine whether Chesterfield Inlet, then the last possibility in the NW corner of the Bay, offered a Northwest Passage. Ascended 100 mi. until the water was nearly fresh and then returned to Churchill in 1761. Returned the following year and traveled to the mouth of the Thelon River in Baker Lake.	Tyrrell (1896).

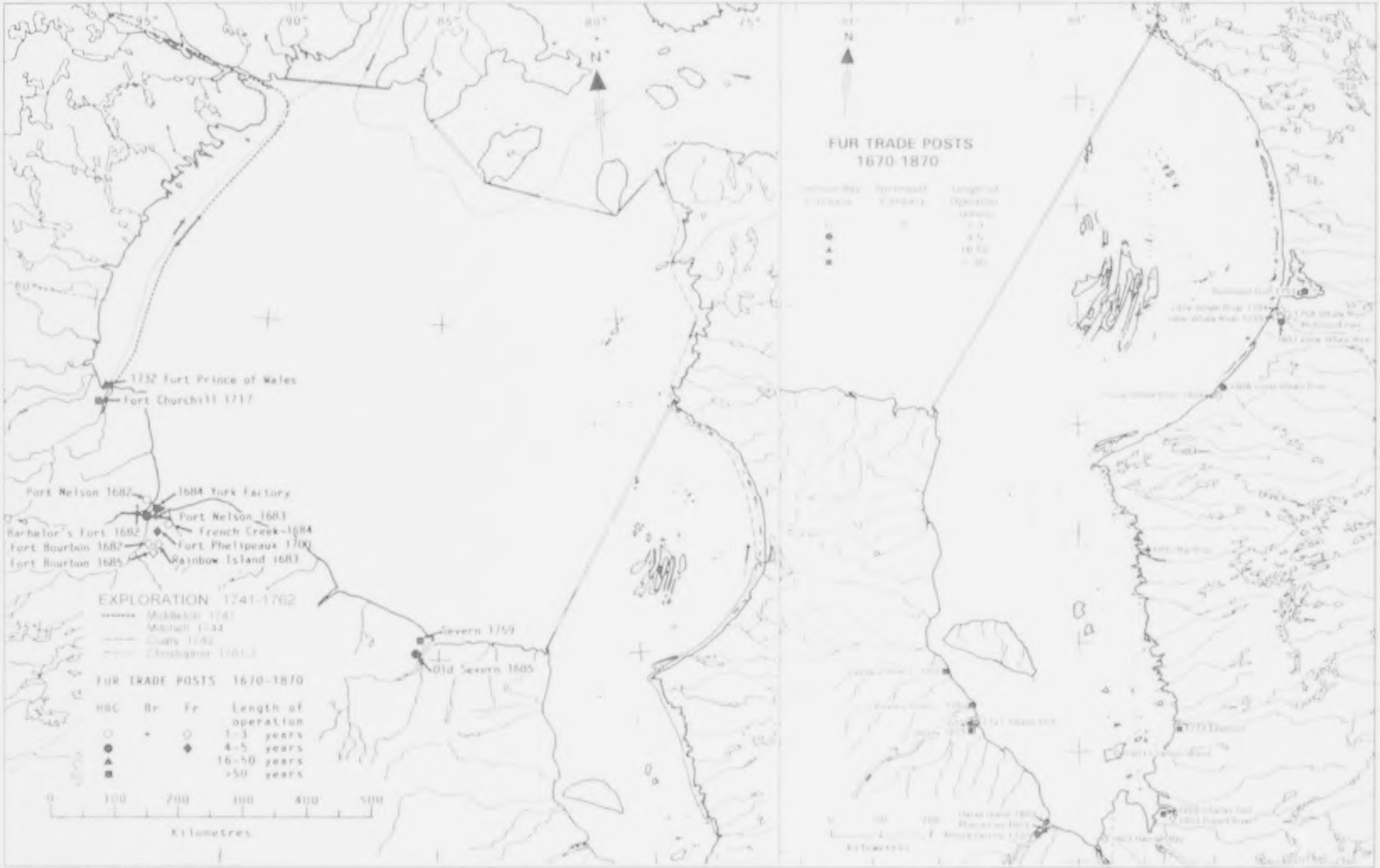

Figure 11-3. Posts of the Canadian fur trade, 1600-1870, and European exploration of Hudson Bay and James Bay 1741-1762 (after Canada 1974).

11.2.3 Development by the Hudson's Bay Company and Whaling (1714-1903)

In 1715, with the French wars over, the HBC consolidated their hold on Hudson Bay and James Bay, repairing or building posts, exploring the coastlines and river networks, trading for furs, and catching whales. Albany settled down to a quiet life preoccupied with the fur trade and, in 1731, construction on Fort Prince of Wales was begun at the mouth of the Churchill River, a location that offered a better harbour than York Factory and was a likely site for a whaling operation (Figure 11-3; Payne 1978-9). The massive stone fort was completed in 1746 and stands, partly restored today. It was a hundred yards square and had more cannons (42) than men. Unfortunately, it was not strategically placed or manned to withstand an assault from the sea, and was surrendered without resistance by Samuel Hearne to Comte de la Perouse in 1782 (Rich 1958; Mathews 1966). York Factory was also captured. Both posts were quickly re-established and continued to play their part in a competion of growing intensity with the successors of the French--the Scottish traders from Montreal. A number of new coastal trading posts were built in James Bay and southeastern Hudson Bay (Figure 11-3), and the company was well able to compete with interlopers and the Northwest Company traders who established posts in the 1790's and early 1800's.

During this period Churchill served as a jumping off point for exploration of the interior to the south and west by Stewart (1715-6), Henday (1753-4), and Hearne (1771) and of Hudson Bay by Middleton (1741-2) and Christopher (1761-2)--to name a few. Competition with the French in the south prompted the HBC to explore northward in hope of establishing new trade with the Indians and perhaps Inuit north of James Bay (Rich 1958; Williams 1963). Despite their monopoly the company still had not explored the eastern coast of James Bay or the southeastern coast of Hudson Bay. Two expeditions were sent to complete the task. The first, led by Captain Thomas Middleton in 1744, explored the coastline from Eastmain north to 56°15'N and discovered Richmond Gulf; the second, led by Captain William Coats in 1749, explored and charted the east coast of Hudson Bay south to and including Richmond Gulf, and selected the site for Richmond Fort (Table 11-2; Figure 11-3).

There were few attempts to diversify commerce or explore outside the bay coasts or major rivers. James Knight was sent in 1719 to discover riches in the northwest, but perished with his entire expedition at Marble Island (Hearne 1795; Smith and Barr 1971; Ross and Barr 1972). A bowhead fishery was tried in the same area between 1765 and 1772, but proved unprofitable (Ross 1979a). One venture that was successful was boat whaling for belugas in the estuaries of the Seal and, to a lesser degree, Churchill rivers (Reeves and Mitchell 1989a) (see Section 14.5). Sloops Cove near the fort served as a mooring for the smaller wooden boats, and its shores bear the signatures of Hearne, Taylor, and others. Oil rendered from these whales contributed significantly to Churchill's exports during much of the nineteenth century, and both Indians and Inuit were employed in the whale capture. Marine travel and the harvest of marine mammals however, do not appear to have ever been an important aspect of Hudson Bay's Indian cultures (Johnson 1961; Trudeau 1968).

The coastal posts in James Bay also served as a jumping off point for later coastal surveys and the first surveys of the interior river routes by Turnor (1778-92), Bell (1869-95), Low (1884-1899), and others (Canada 1974). Turnor surveyed the coast of James Bay from Fort Rupert west, and travelled inland along the Albany and Moose river systems; Bell surveyed this region's east coast from Attawapiskat northward, and travelled inland along the Nottaway and Attawapiskat rivers; and Low surveyed a short stretch of coastline between Rupert Bay and Eastmain and the coast of Akimiski Island, and travelled inland along the main rivers of this region's east coast.

While trade with the Indians flourished throughout this period, the HBC did not make a serious attempt to trade with the Inuit of southeastern Hudson Bay until 1750, when the Richmond Gulf post was built on the southern edge of Inuit territory (Francis 1979; Saladin d'Anglure 1984). Relations between the traders and Inuit were strained and suspicious, and the Inuit may have considered the traders to be allies of their Indian enemies. In 1754, Inuit ransacked a summer outpost and whaling station at the Little Whale River and killed a young HBC employee (Rich 1958; Francis 1977). Two Inuit were later killed. In 1758, the Richmond Gulf post was dismantled and moved to Little Whale River, where it closed the following year for lack of trade. A temporary post established at Little Whale River in 1791, was abandoned in 1792 when the five employees were massacred by Indians or Inuit. Indeed, there was very little contact between Inuit and whites in this area until about 1839 when Inuit began trading at Fort George (Chisasibi) (Francis 1979; Saladin d'Anglure 1984).

The HBC twice attempted to develop commercial whaling for belugas in southeastern Hudson Bay (Francis 1977; Reeves and Mitchell 1987a). The first, in the 1750's at Little Whale River, used Indian manpower and methods but was not profitable. It was abandoned in 1759, although sporadic attempts were made to revive the fishery and company sloops continued to trade with the Indians for whale oil. The main commercial whaling was conducted by the HBC between 1852 and 1868 at the Great Whale and Little Whale rivers. The peak decade was 1854-63 when, with the help of Indians and Inuit, the company harvested at least 7,176 whales from the two rivers using whale nets or harpoons (Reeves and Mitchell 1987a). Oil was rendered from the blubber for use as lamp fuel, and the skins were salted for use as a leather substitute (Francis 1977). Catches declined sharply in the late 1860's and the fishery was abandoned in 1869. Commercial whaling played a minor role in the history of the James Bay, where there were no large summer concentrations of bowheads or belugas to be harvested (see also Section 14.5).

Prior to east-west railway development, Hudson Bay and the Nelson River afforded some of the best access to the interior of North America, and the harsh conditions of the Bay took a significant toll on the supply ships (see Section 15.3, Table 15-9 for a listing of wrecks). Beginning in 1811, the Red River settlement was colonized by Scottish and Swiss immigrants who arrived via Hudson Bay and the Nelson River. This immigration was instrumental in keeping Manitoba and the territories to the west as part of the new Dominion of Canada (Neatby 1968). The Hudson's Bay and Northwest companies were amalgamated in 1821, and for some years York Factory enjoyed peaceful prosperity as the principal port of entry for a trade that extended across the continent (Neatby 1968). By Confederation, the establishment of cheaper southern railway routes had diverted much of the trade south, and York Factory was relegated to a supply post for other stations in the area. Two years later the Hudson's Bay Company's juridsiction over Rupertsland was transferred to the Government of Canada, and for a generation the bay relapsed into obscurity.

The decline of York Factory as a port of entry coincided with the growth of the whaling industry in northwestern Hudson Bay (see also Section 14.5). Declining whale stocks in the north Atlantic prompted American and Scottish whalers to enter the bay in 1860 and begin their unregulated harvest of the region's bowhead whale stocks (Ross 1974, 1975, 1979a+b; Reeves et al. 1983). American vessels operating from ports in New England did most of the whaling. Whalers rarely visited without securing the help of Inuit to provide fresh meat and catch whales (Ross 1974, 1975, 1979b, 1984; Eber 1989).

The major river systems continued to serve as an easy route to the interior and the HBC developed a network of inland posts in the James Bay drainage basin (Canada 1974). Supplies for the inland posts were transported to the James Bay posts by ship and then inland along the rivers by scows or other means (Howell 1970). Diversification from the largely Hudson's Bay Company development began with the establishment of missions at Moose Factory and Fort George in the 1840's and 50's (Howell 1970; Preston 1981), and continued slowly over the next half century. This region became part of Canada in 1870, the year after the HBC surrendered Rupert's Land to Britain.

For the aboriginal peoples, the presence of Hudson's Bay Company trading sloops working along the coast from the early eighteenth century onward and contact with fur traders, explorers, and whalers marked the beginning of important changes in material culture and economic life (Jenness 1932; McIntosh 1963; Damas 1968; Trudeau 1968; Crowe 1974; Ross 1975; Ray 1977; Honigmann 1981; Preston 1981; Saladin d'Anglure 1984; Ens 1987). Traditional patterns of seasonal movement were interrupted to take advantage of opportunities to obtain trade goods; hunting practices were modified through the introduction of rifles, and need to procure furs and meat to exchange; and aboriginals were exposed to radically different concepts of time, work, and behaviour, and to new languages, social activities and diseases.

Indian and Inuit alike were decimated by disease (Jenness 1932). Indeed, all but 5 of the Sadlirmiut of Southampton Island died of a virulent gastric or enteric disease introduced by Scottish whalers on the steam whaler Active (Low 1906; Comer 1910; Munn 1919; Ross 1984). Whalers then settled Aivilingmiut from the Wager Bay-Repulse Bay area onto Southampton Island to help with whaling and to hunt and trap foxes (Munn 1919). By that time the bowhead population had already been reduced severely, and whaling was no longer profitable. The whalers stopped coming and Inuit who had depended on them for their livelihood were left to cope.

By about 1900, the Inuit were venturing south to trade at the post on Charlton Island, and trapping on a number of the islands in James Bay (i.e., Cape Hope, Strutton, and Charlton islands; Schwartz 1976; Saladin d'Anglure 1984). Weetaltok, a noted Inuit leader, moved his family from the Belchers to the Cape Hope Islands area; he sometimes trapped on Charlton Island. By 1935 there were eight Inuit families living in the area. They sometimes hunted, fished and camped with the coastal Indians, and moved to Great Whale River in 1960.

11.2.4 Settlement (1903- present)

In 1903, the French trading company, Révillon Frères, began building trading posts in this region to compete with the HBC (Honigmann 1981; Preston 1981; Saladin d'Anglure 1984). Competition was strong until the Great Depression, which forced closures of many of the marginal northern posts creating great hardship for the Inuit. In 1936, Révillon Frères was absorbed by the HBC and the French departed. Throughout this period there was a gradual abandonment of seasonal camps and slow but irreversible sedentarization around the missions and trading posts. In Quebec, the last inland Inuit moved to the coasts in the 1930's (Saladin d'Anglure 1984)(Table 11-3).

Modern settlement of the Hudson Bay coasts began in 1911 with the establishment of a Hudson's Bay Company post at Chesterfield Inlet, and by the 1930's the company had established posts around the bay (Table 11-3) (Brack 1962; Brack and McIntosh 1963; Fried 1968; Usher 1971; Welland 1976; Finley et al. 1982; Outcrop Ltd. 1984). Church missions and detachments of the Royal Canadian Mounted Police were erected at some of the locations, and permanent settlements began to develop. Declining game resulted in famine among some of the Inuit groups, such as the Padlei people (Harrington 1981), and encouraged the growth of centralized coastal settlements where there were opportunities for employment in mining, building, fish and marine mammal harvesting and processing (see above), and other fields. Vivid, first-hand accounts of the early settlement period have been published by many scientists (e.g., Rasmussen 1927; Twomey and Herrick 1942), traders (e.g., Mallett 1925; Campbell 1951; Anderson 1961; Lyall 1979; Hunter 1983; Robinson 1985; Copland 1985), and missionaries (e.g., Renison 1957; Marsh 1987).

A number of major transitional events followed: the completion of the railway to Moosonee in 1931; construction of radar bases in the mid 1950's; and hydroelectric development in northern Quebec (Damas 1968; Trudeau 1968; Howell 1970; Honigmann 1981; Preston 1981; Saladin d'Anglure 1984). Railway construction facilitated access to the region and changed the routing of supplies to many of the coastal and inland posts and settlements. It made Moosonee an important distribution centre for supplies, and for administration of the Ontario communities. By the late 1940's game was declining and fur prices were relatively low (Honigmann 1981). In the mid-1950's, construction of Mid-Canada Line radar sites at Fort Albany and Kuujjuarapik, and of a Pintree Line site at Moosonee, attracted workers to those communities, many of whom remained after the bases were closed in the 1960's and 1970's. By the 1960's most aboriginal people had abandoned their traditional seasonal camps for the coastal settlements to take advantage of schools, health care facilities, and opportunities for wage employment. In the 1970's, major hydroelectric developments in northwestern Quebec provided work and improved services to residents of the east-coast communities. This process will continue and expand if planned developments on the Rupert and Eastmain river systems proceed. Modern development is discussed further in Chapter 15 on Development.

Table 11-3. Coastal settlement of Hudson Bay and James Bay (see Trudeau 1968; Howell 1970; Barger 1981; OMNR 1985; Canada 1990; Outcrop Ltd. 1990; HBC Archives: Post histories). Dashes indicate continuous (-) or discontinuous (- - -) post operation or settlement.

Settlement	Modern Development	History
Akulivik (Cape Smith)	1922 - present	HBC post on Smith Island at 60°44'N, 78° 28'W and operated from 1924-52.
Arviat (Eskimo Point)	1921 - present	First trading post established by the HBC in 1921. Catholic mission established in 1924. Anglican mission in 1926.
Attawapiskat	1892 - present	An Oblate mission was erected at the mouth of the Attawapiskat River in 1892. It drew Indians to the area and prompted the HBC (1901) and Révillon Frères (1906) to establish trading posts. A permanent mission was established about 1912. A disastrous flood nearly destroyed the community in May 1934.
Baker Lake	1924 - present	Posts operated by Révillon Frères 1924-1936, HBC 1925-present, and Ramey and Patterson 1961-62. Anglican and Catholic missions established in 1927. Temporary RCMP detachment 1915-18, permanent in 1938.
Baker Lake Narrows	1920 - 1922	Post located on the south side of the eastern entrance to Baker Lake at 63°59'N, 94°13'W. Operated by Lamson and Hubbard.
Big Hips Island	1914 - 1926	Operated by the HBC, closed in favor of Baker Lake. Approximate location 64°07'N, 95°40'W.
Bury Cove	1919 - 1920	HBC post. Approximate location 65°26'N, 87°05'W.
Chesterfield Inlet	1911 - present	HBC post established in 1911. Lamsom and Hubbard operated a competing fur trade post from 1920-22. Catholic mission established in 1912. RCMP post moved there from C. Fullerton in 1914.
Chisasibi	1803 - - -1837-present	In 1803 the HBC built a post at the "Big River" to counteract Northwest Company activity in the area. The NWCo. post was abandoned in 1806. The HBC post, renamed Fort George, has operated continuously since 1837. Due to hydroelectric development of the La Grande River, the village was moved from its historic site on Governor's Island to create the new village of Chisasibi on the river's south shore in 1980 (Perreault-Dorval 1982; Canada 1990).
Churchill	1929 - present	Canadian National Railways reached the mouth of the Churchill River in 1929. This was soon followed by construction of harbour facilities, grain elevators, and accommodations. Airbase established by USAF in 1942.
Coats Island	1918 - - - 1928	HBC post located in a small unnamed harbour at 62°55'N, 81°57'W. Moved to Coral Harbour in 1924, but reopened in 1927-28.
Coral Harbour	1916 - - - present	Independent post near Seal Point 64°07'N, 83°11'W operated by Henry Toke Munn from 1916-18. HBC post, known as the Southampton Island post moved from Coats Island in 1924. Anglican mission established in 1924, Catholic in 1927. A large airfield built during WW II was taken over by the Ministry of Transport in 1948.
Eastmain	1723 - - -1870-present	Before building a post at Eastmain, in 1723, the HBC often wintered a sloop there to trade with the Indians. It was often overshadowed by the post at Waskaganish, and remains one of the smaller communities in the region.
Fort Albany	1674 - present	The HBC established a post on the south shore of the Albany River in 1674, and they have operated a post at the river mouth, sometimes on Albany Island, almost continuously since then. Albany was the main Ontario distribution point of supplies for the interior fur trade until about 1912 when railway construction provided easier routes inland. (See Kashechewan).
Fullerton Harbour (64°00'N, 89°00'W)	1913 - 1919	Operated by F.N. Monjo and Co.; sold to the HBC and closed.
Inukjuak (Port Harrison) (Inoucdjouac)	1921 - present	HBC post established in 1921 and in active competition with a Revillon Freres post in the 1920s and early 1930's.
Ivujivik (Ivugivik) (Wolstenholme)	1938 - present	Mission established in 1938. HBC post moved from Wolstenholme ("Erik Cove") on Hudson Stait to Ivujivik in 1947.
Kapiskau	?	Seasonal HBC post established at the mouth of the Kapiskau River, on the north side. Site of a goose hunting camp.
Kashechewan	late 1950's-present	Kashechewan is a largely Cree community on north side of the Albany River about 8 km from Fort Albany. Residents of Fort Albany and Kashechewan were originally part of a single community on an island midway between the present villages. In the mid-1950's, when the mid-Canada line base was built at the present site of Fort Albany, most of the Anglicans settled at Kashechewan and the Catholics at Fort Albany. The communities remained separate after the base closed.
Kuujjuarapik	1804 - - -1857-present	The Northwest Company and HBC operated posts for short periods between 1804 and 1857, often for seasonal trade or summer whaling at the river mouth. A permanent post was established by the HBC in 1857, and in 1891 this post became the main site for trade in southeastern Hudson Bay (Barger 1981). A radar control base was constructed in 1955, forming the nucleus for the modern community. When military operations were phased out in 1967, Kuujjuarapik became a regional centre for federal and provincial governments. It is one of the few communities where Cree and Inuit live together in significant numbers.

Settlement	Modern Development	History
Lake River	c. 1928-1950	Outpost of the Hudson's Bay Company post at Attawapiskat.
Maguse River	1925 - 1926	Situated on the right bank at the river mouth, 61°17'N, 94°04'W. Independent trading post owned by Oscar Sigurdson. Operated by Sigurdson and Martin from 1942 to 1949.
Mansel Island	1925 - 1949	HBC post at Swaffield Harbour 62°23'N, 79°44'W. Originally an outpost of Wolstenholme, Quebec.
Moose Factory	1673 - - -1730-present	Moose Factory, on Factory Island in the Moose River, was founded by the HBC in 1673. It is the oldest English-speaking settlement in Ontario, and was a major administrative and trans-shipping centre for the HBC in lower Hudson Bay prior to World War I. The community is connected to the mainland by freighter canoe or ferry in summer, and by helicopter for the remainder of the year.
Moosonee	1903 - present	The first permanent settlement on the north shore of Moose River at Moosonee was a Revillon Freres trading post established in 1903 to compete with the HBC post at Moose Factory. Moosonee became the northern terminus of the Temiskaming and Northern Ontario Railway, now the Ontario Northland Railway in 1931. Ontario's only seaport, it was soon the main distribution point for supplies destined for many of the James Bay communities. A Pinetree Line radar base built there in the early 1960's closed in 1975. Moosonee is the Ontario government centre for the region.
Peawanuk	1986 - present	In May 1986, spring floods swept away much of the original settlement at Winisk, which had been located about 6 km upstream from Hudson Bay, and people relocated 30km southwest to Peawanuck.
Povungnituk	1923 - present	HBC post established in 1923.
Rankin Inlet	1957 - present	Established as a mining centre by the North Rankin Nickel Mines in 1955. HBC store built in 1957. Hospital, government offices, school, and 3 churches were added between 1954-60. Mine closed in 1962 leaving the community with a wage-based economy.
Repulse Bay	1920 - present	HBC established a post on Repulse Bay in 1920. Révillon Fréres also operated a post there from 1924-36. A Roman Catholic mission was built in 1932 and permanent settlement began in the early 1960's with the construction of rental homes.
Richmond Gulf	1750 - - - 1956	Various companies operated posts for short periods in various locations between 1750 and 1956.
Sanikiluaq	1928 - present	HBC established a seasonal trading outpost near the south tip of Flaherty Island in 1928. In 1934, its status was raised to post, and the buildings were shifted to Tukarak Island. It was moved to the present site of Sanikiluaq in 1961, and other facilities followed.
Severn	? - present	Apparently gradual growth from early fur trade beginning.
Tavani **(62°04'N, 96°06'W)**	1928 -1951	Fur trade post owned by Révillon Fréres from 1928 until its sale to the HBC in 1931. HBC outpost of Chesterfield Inlet until 1935.
Umiujaq	1986 - present	Inuit who relocated from Kuujjuarapik established this community on the coast of southeastern Hudson Bay. It was inaugurated in 1986.
Vieux Comptoir	1938 -1959	The HBC began operating a "camp trade" from Eastmain at Vieux Comptoir (Old Factory) in 1938. The operation was later upgraded to a store, which was closed in 1959 and moved to Wemindji.
Wager Bay	1926 - 1947	HBC post located at 65°55'N, 90°50'W.
Waskaganish	1668 - - - 1813-present	Waskaganish (Rupert House) was established in 1668, before the HBC was incorporated. It was built during an exploratory trip to assess the fur trade potential of the area, on the ruins of Henry Hudson's house, and is the oldest HBC establishment in North America. The post was captured by the French in 1686. It was closed for much of the next 100 years, but has operated continuously since 1813, serving as a supply point to support expansion of the HBC toward Nemiscau and MIstissini.
Wemindji	c.1959 -present	The HBC store at Vieux Comptoir was moved to Wemindji c. 1959 to take advantage of the good harbour.
Whale Cove	1962 - present	Community established as a permanent settlement in 1959 when the government moved inland Caribou Inuit who had survived the famines of 1957-58 the coast. Issatik Eskimo Co-operative was formed in 1962 to harvest and market beluga and operate a store.
Winisk	circa 1900-1986	A church mission established at Winisk prompted the HBC to establish a post there about 1900. Postwar radar base of the Mid-Canada Line closed in 1965. Spring flooding in 1986 swept away much of the community and most of the people relocated to Peawanuk about 30 km inland.

[1] Dashes indicate continuous or discontinuous operation.

Government interest in the natural resource potential of Hudson Bay prompted oceanographic explorations that began in earnest with the Loubyrne in 1929 and in James Bay with the Labrador in 1955, and continue today (Table 5-1). Since then scientists have examined many aspects of the region's fishery and mineral potential, summaries of which are presented in the preceding sections.

Remarkably, the Belcher Islands, which appeared on maps before 1748 (Drage 1748), were not rediscovered until 1914. Flaherty (1918) is generally credited with their 'discovery', but Renouf (1921) actually beat him onto the main islands while recovering the stranded Fort Churchill. In any event, Flaherty explored and mapped the islands later the same year.

Today, there are thriving modern communities scattered along the coasts of James Bay and Hudson Bay, and Inuit and Cree are involved in all aspects of their government and economy. Linked to the south by satellite and various modes of transportation (see Section 15.3), they have roads, supermarkets, hospitals or nursing stations, schools, and limited visitor accommodation. Moosonee, Moose Factory, and Churchill, which are serviced by passenger train, have a well-developed tourist industry with hotels, museums, and scenic tours. The Eskimo Museum at Churchill is perhaps the finest of its kind, and exhibits many aspects of maritime Inuit culture.

Marine resource harvesting still plays an important part in the Inuit and, to a lesser extent, Cree cultures and local economy. These harvesting activities are described in Chapter 14, and in earlier chapters on fish, birds, and mammals. Coastal travel between adjacent communities is common either by boat when there is open water or by snowmobile on the landfast ice.

Large areas of the coastal mainland, and the Belcher Islands area, have been reserved for the use of Cree and/or Inuit under historical treaties or comprehensive land claims settlements. Treaty Nine in 1905 and the James Bay Treaty (No. 9) in 1929-30, between the Government of Canada and the Cree and Ojibwa people of northern Ontario, created a number of small reserves along the west coast of James Bay, at Moose Factory Fort Albany, Attawapiskat, Winisk and Fort Severn (OMNR 1985; Morrison 1986). The James Bay and Northern Quebec Agreement between the governments of Canada and Quebec, the Cree and Inuit of northern Quebec, and Hydro-Quebec was the first comprehensive land claim settlement in Canada reached through a process of negotiation (Quebec 1991; Canada 1992) (Figure 11-4). It does not address land use planning as a topic or requirement or include offshore waters, but does affect coastal development in northern Quebec. The Makivik Offshore Claim, which is under negotiation, will cover the coastal areas around western and northern Quebec, and could give beneficiaries marine rights similar to those in the Nunavut Land Claims Agreement (1992). That agreement, between the Inuit of the Nunavut Settlement Area and the Government of Canada, was ratified by the Inuit in November 1992 and passed by the Senate in June 1993 (TFN and DIAND 1992; Canada 1993). Its provisions include Inuit ownership of large areas of land adjacent to Hudson Bay, and Articles relating to land and resource use, resource management, marine areas, and the establishment of parks (Figure 11-5). The effects of these agreements on harvesting are discussed in the Chapter 14. Indian claims under the Northern Flood Agreement in Manitoba and for outstanding Treaty Land Entitlements along the southwestern coast of Hudson Bay are ongoing (L. Bernier and G. Campbell, DIAND, Winnipeg, pers. comm.) (Figure 11-6).

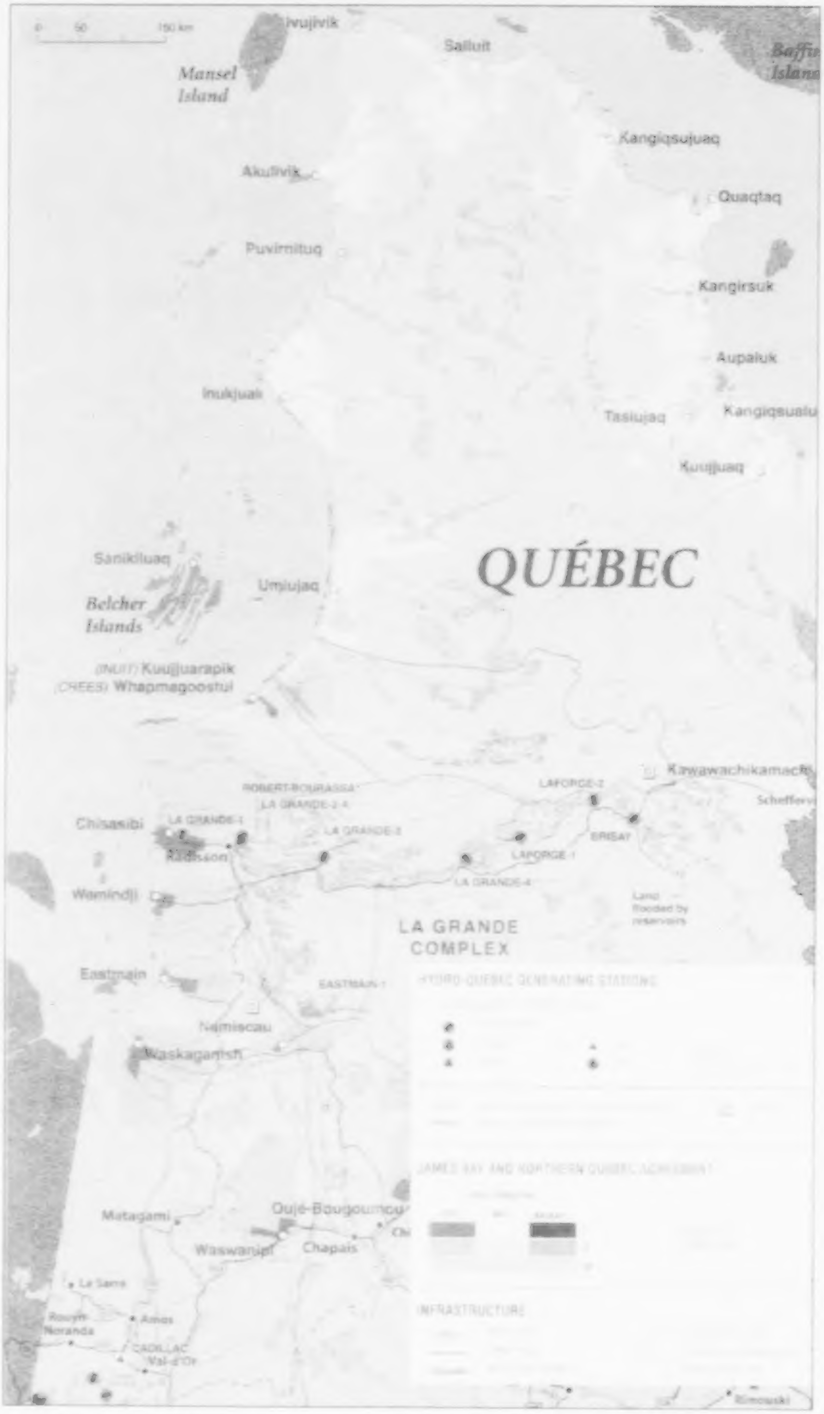

Figure 11-4. Land claims settlements under the James Bay and Northern Quebec Agreement and Quebec Hydro generating stations in the Hudson Bay watershed (adapted from Hydro Quebec 2001, p. 68).

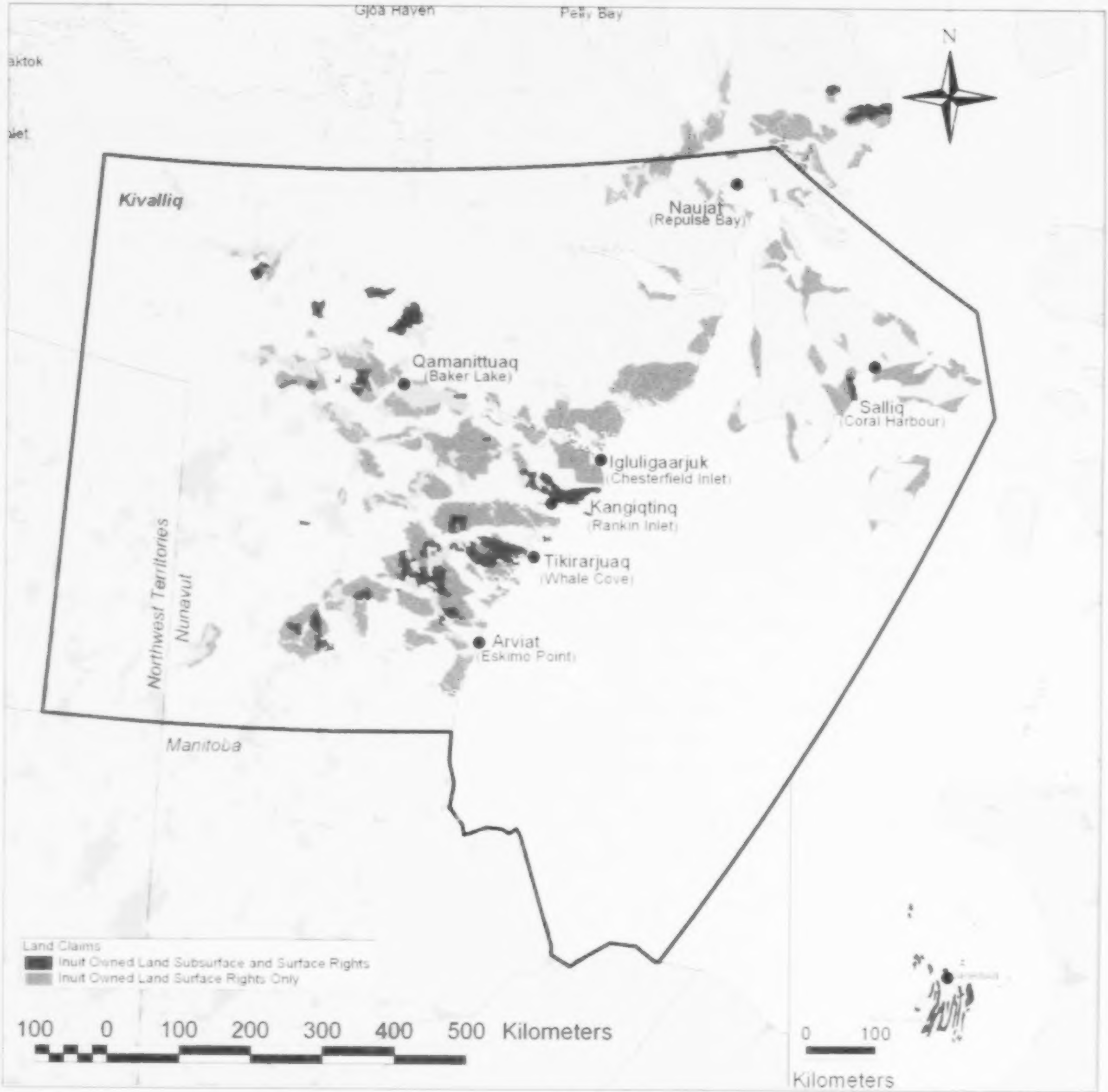

Figure 11-5. Inuit owned lands under the Nunavut Final Agreement.

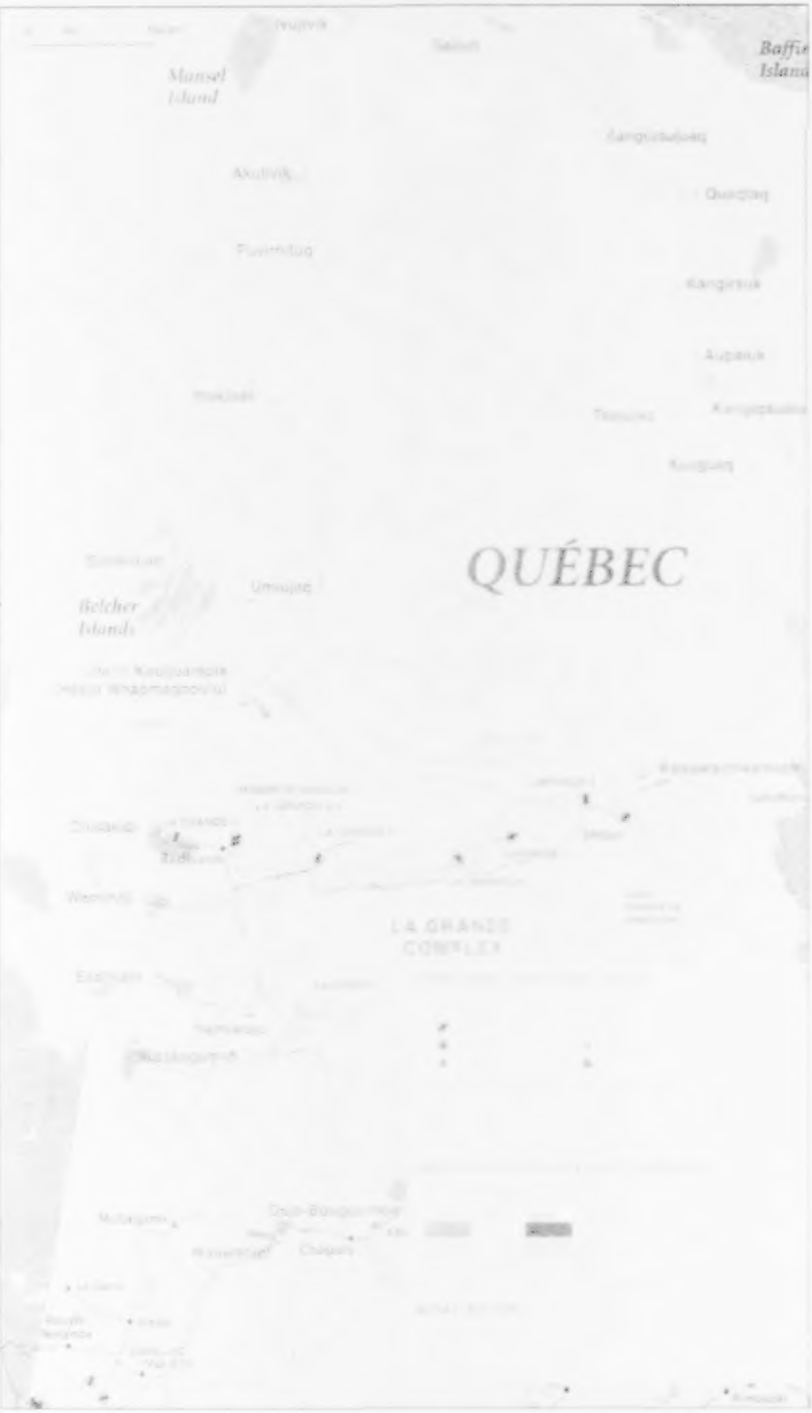

Figure 11-4. Land claims settlements under the James Bay and Northern Quebec Agreement and Quebec Hydro generating stations in the Hudson Bay watershed (adapted from Hydro Quebec 2001, p. 68).

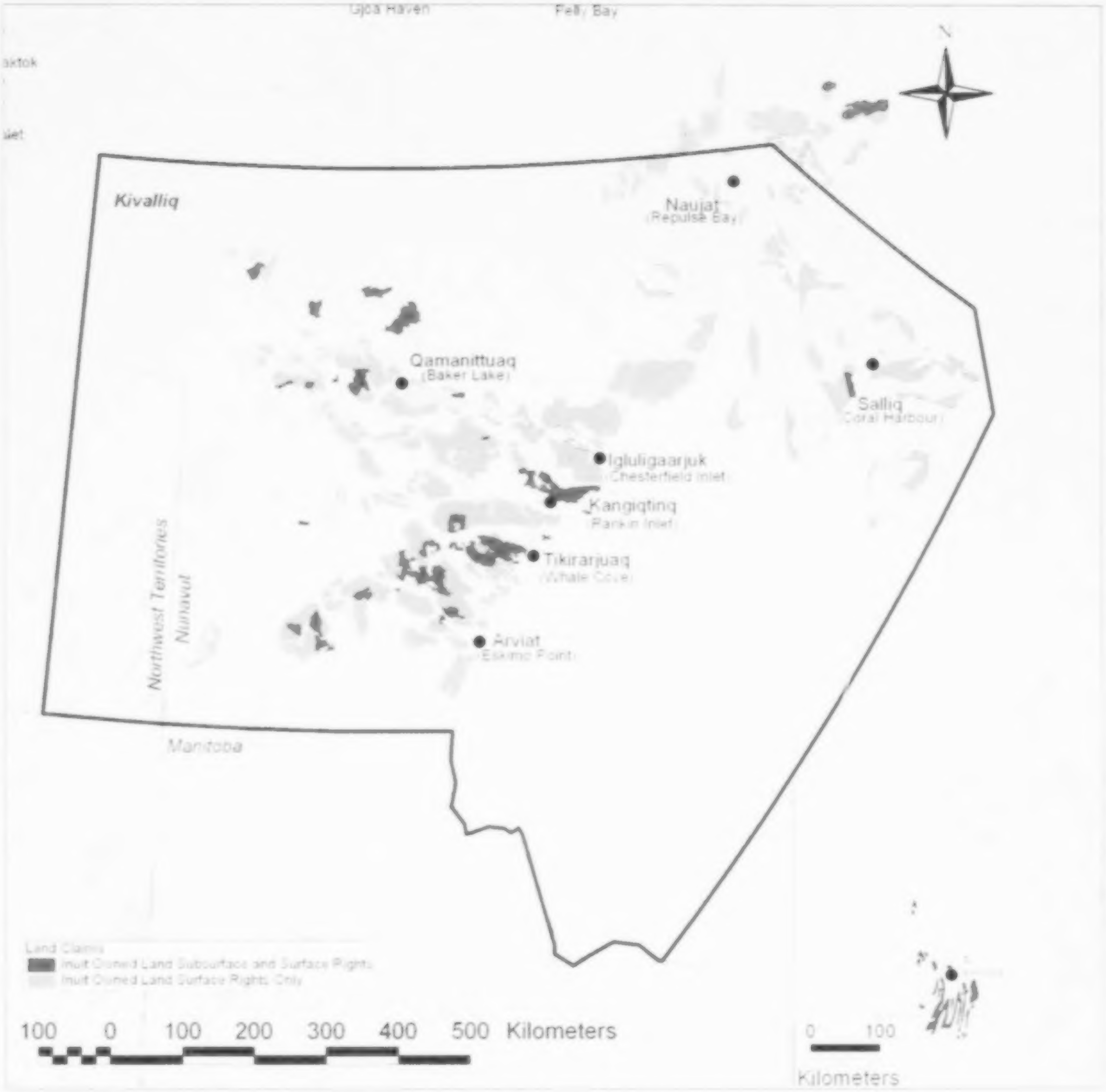

Figure 11-5. Inuit owned lands under the Nunavut Final Agreement.

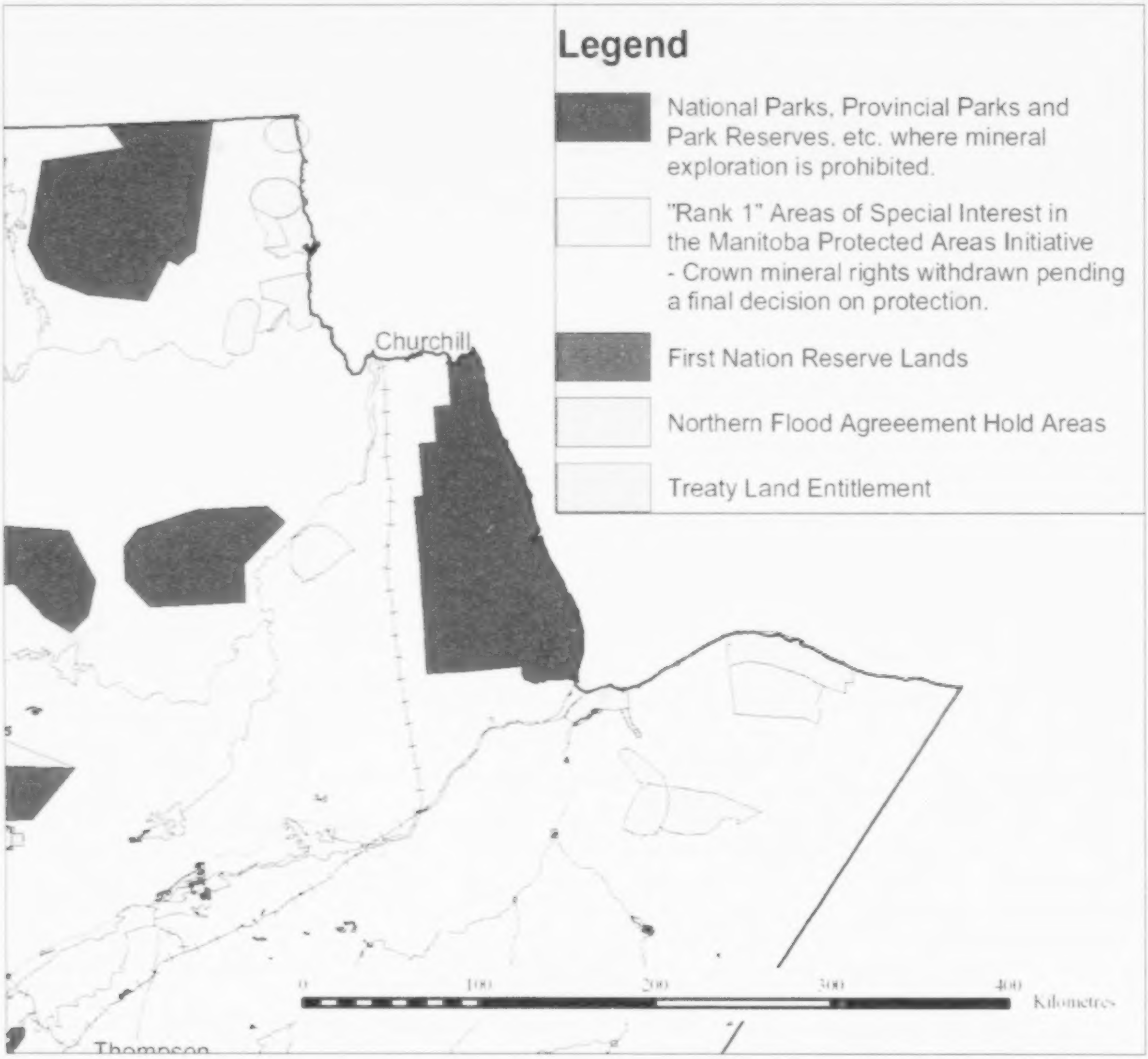
Legend
National Parks, Provincial Parks and Park Reserves, etc. where mineral exploration is prohibited.
"Rank 1" Areas of Special Interest in the Manitoba Protected Areas Initiative - Crown mineral rights withdrawn pending a final decision on protection.
First Nation Reserve Lands
Northern Flood Agreeement Hold Areas
Treaty Land Entitlement
Churchill
Thompson
0
100
200
300
400
Kilometres

Figure 11-6. **Protected Lands and "Rank 1" Areas of Special Interest in Manitoba, May 2004 (from http://www.gov.mb.ca/itm/mrd/geo/exp-sup/sup-pdfs/fig10.pdf).**

11.3 SUMMARY

The prehistorical record of human occupancy of this region's coasts is relatively short due to glaciation. Paleo-Eskimos from Alaska colonized the islands and coasts of Hudson Bay after glaciation and gave rise to the Pre-Dorset (2000-800 BC) and later Dorset (800 BC-1500 AD) cultures. A later invasion of Alaskan Eskimos gave rise to the Thule culture (1000-1600 AD), direct ancestors of the modern Inuit. Each culture had a more advanced marine hunting technology than the last, and the Thule people actively hunted bowhead whales for food and building materials. Sites of prehistoric Inuit occupation are found along the Quebec coast from the Grande rivière de la Baleine northward, from Churchill northward along the west coast, on Southampton Island, and on the islands of southeastern Hudson Bay. They are relatively common but not unique to this region, which appears to have been marginal for these cultures. Some of the latest Dorset sites are located near the entrance to Richmond Gulf. In prehistoric times, ancestors of the Cree occupied the northern woodlands of Quebec, Ontario and Manitoba west to near Churchill, while Chipewyans occupied the area near Churchill. The extent of coastal use by prehistoric Indian peoples is not well known.

The region's historical record is long in North American terms. Early European exploration (1610-1632) of southeastern Hudson Bay and James Bay was in search of a Northwest Passage to the Orient. When no passage was found there was a brief hiatus, until about 1668 when interest in the lucrative North American fur trade prompted renewed explorations and, soon after, construction of Hudson's Bay Company trading posts at Fort Albany, Moose Factory and Fort Rupert. An intense struggle for the control of this region ensued between French and British interests, ending only with the Treaty of Utrecht in 1713, wherein France relinquished all claims to Hudson-James Bay. All of the company's James Bay posts changed hands during the conflict, and for much of the period Albany was their only foothold in Hudson-James Bay.

Over the next 190 years the Hudson's Bay Company consolidated its hold on this region, establishing posts, developing the fur trade, and catching beluga whales at Grande rivière de la Baleine and Petite rivière de la Baleine. The coastline was mapped and, in the 1850's, the first church missions were established. While trade had been brisk with the East Main and West Main Cree since 1669, there was little contact between traders and Inuit until the 1840's.

The region continued to serve as an easy route to the interior until the advent of cheaper southern railway routes in the mid-1800s. The decline of York Factory as a port of entry coincided with growth of bowhead whaling in northwestern Hudson Bay. Between 1860 and 1915, New England and Scottish whalers nearly extirpated the bowhead population in northwestern Hudson Bay. Modern settlement began in 1912 with the establishment of a Hudson's Bay Company post at Chesterfield Inlet, and today there are settlements around the coast.

While the earliest explorers left little evidence of their visits, later explorers, fur traders, missionaries, and settlers had a marked effect on the cultures and economies of the aboriginal peoples. Centralized, permanent coastal settlements replaced temporary seasonal camps, as guns and motorboats replaced the bows and kayaks. Aboriginals were exposed to radically different concepts of time, work, and behaviour; and to new languages, social activities, and diseases. Despite changing culture and technology, marine resource harvesting still plays an important part in modern Inuit culture and economy and, to a lesser extent, that of the coastal Cree. Land settlement agreements have confirmed Cree and Inuit title to large stretches of the Quebec coast, and Inuit title to large areas of Nunavut.

Some of the key differences among the modern coastal settlements are the railway links to Moosonee and Churchill; the all-weather roads to communities along the Quebec coast of James Bay; and the influences of radar base and hydroelectric construction. Kuujjuarapik and Chisasibi are unusual in that both Indians and Inuit inhabit them. Moosonee is Ontario's only saltwater port; Churchill is Manitoba's only saltwater port and the region's only deepwater port.

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12.0 PROTECTED AREAS AND SENSITIVE HABITATS

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To have true standing a protected area must be established in law. Important habitats within and adjacent to the Hudson Bay marine ecosystem have been afforded legislated protection in a number of forms. These include National, Provincial and Territorial parks, Migratory Bird Sanctuaries, Territorial Game Sanctuaries or Preserves, National Historic Sites, and Canadian Heritage Rivers (Figure 12-1). Each of these offers a different type of protection and is administered and managed differently; most have been, or will be, affected to a greater or lesser degree by recent land claims settlements (Quebec 1991; Canada 1992, 1993; TFN and DIAND 1993). Each of these types of protected areas will be discussed briefly as it pertains to the Hudson Bay marine ecosystem. A brief discussion of sensitive habitats that have been identified as important but remain unprotected will follow.

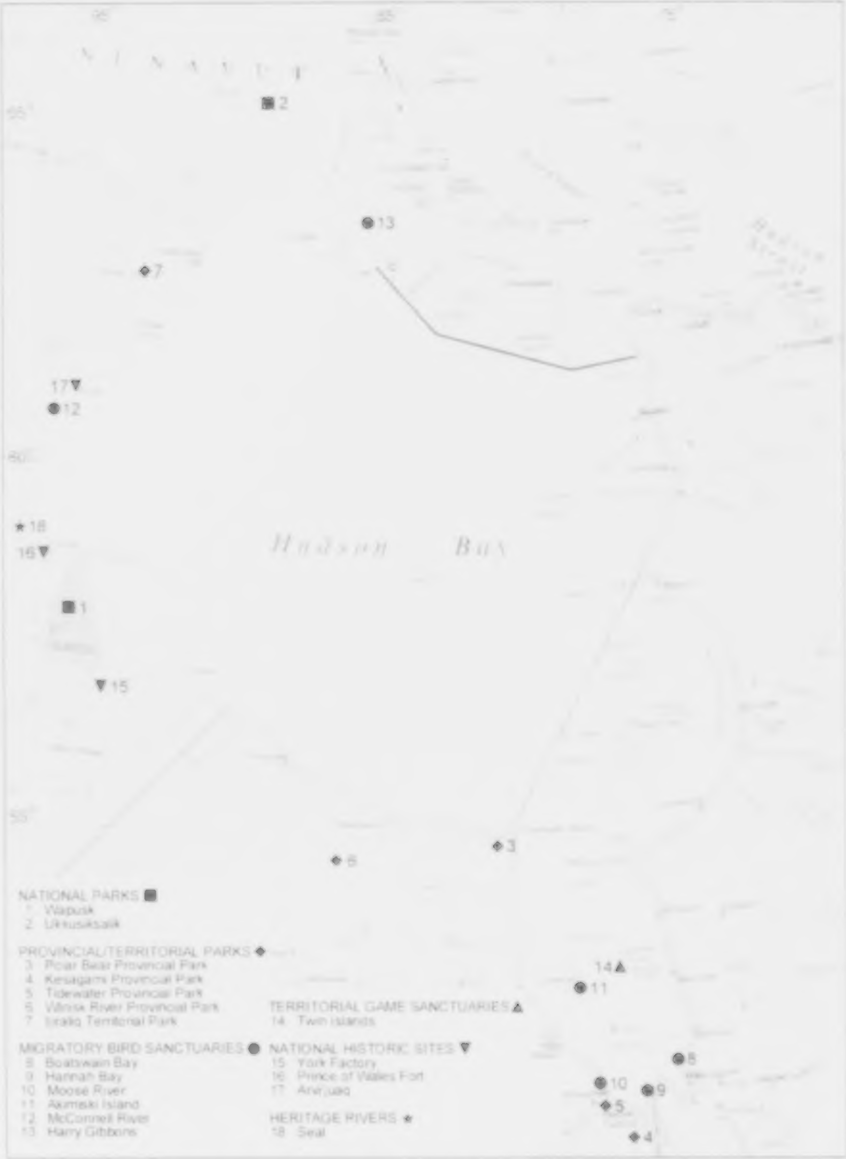

Figure 12-1. **Map of Hudson Bay and James Bay showing locations of protected areas (adapted from Canadian Geographic 1999). The northern boundary of the Hudson Bay marine ecosystem is shown with a heavy black line; a thin black line separates the Hudson Bay (north) and James Bay (south) marine regions of the ecosystem.**

12.1 NATIONAL PARKS

Parks Canada Agency (hereafter Parks Canada) has a mandate to protect important natural areas and historic sites in Canada, and to encourage public appreciation, understanding, and enjoyment of them.

12.1.1 Terrestrial

Parks Canada has divided the Canadian landmass into 39 different natural regions - each representing a different and distinct Canadian landscape. Their goal is to ensure that there is at least one national park in each of these regions to create a National system that protects examples of each of Canada's landscapes. To date, two National Parks, Wapusk and Ukkusiksalik, have been established bordering the Hudson Bay marine ecosystem. Two other other areas are currently under consideration as future National or Provincial parks, the Lake Guillaume Delisle and Eau-Claire Lake area, and the Povungnituk Mountains—both in northern Quebec.

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Wapusk National Park, which represents the Hudson-James Lowlands Natural Region, was established on 24 April 1996. This wilderness park is situated east of Churchill Manitoba and protects an area of 11,475 km^2 that extends southward from Cape Churchill (Figure 12-2). The park's natural heritage resources are of international, as well as national, significance. It includes one of the world's largest known polar bear denning areas, and vital habitat for hundreds of thousands of waterfowl and shorebirds that nest along the coast of Hudson Bay or gather and feed there during the annual spring and fall migrations. A board consisting of representatives of the federal and provincial governments, the Town of Churchill, and the First Nations of Fox Lake and York Factory manages the park.

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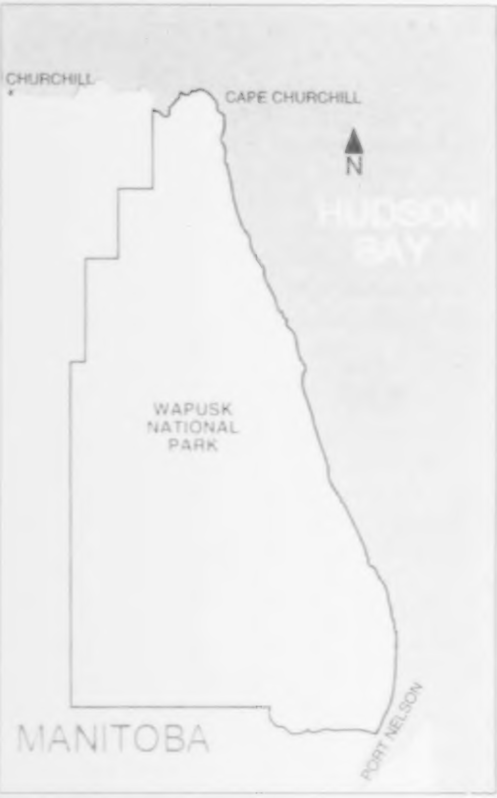

Figure 12-2. **Wapusk National Park (adapted from New Parks North, March 1997).**

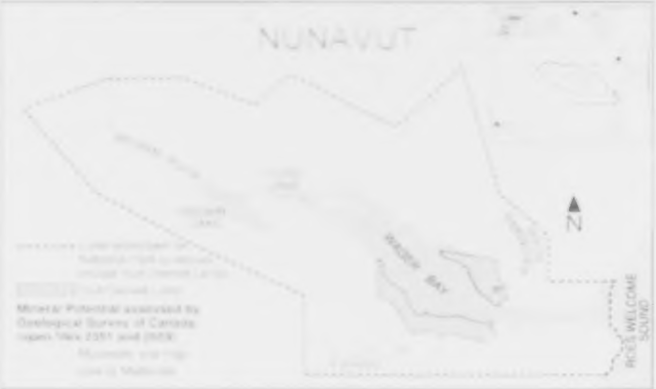

Figure 12-3. **Ukkusiksalik National Park (Wager Bay) (adapted from New Parks North, March 2003).**

Ukkusiksalik National Park, which represents the Central Tundra Natural Region, was established on 23 August 2003. This wilderness park extends westward from Roes Welcome Sound to include Wager Bay and the Brown and Piksimanik rivers, encompassing an area of 23,500 km^2 and most of the Wager Bay watershed (Figure 12-3). It includes a variety of landforms and wide range of habitats. Inuit residents from the Kivalliq communities, mainly Chesterfield Inlet, continue to travel to the area to hunt and fish.

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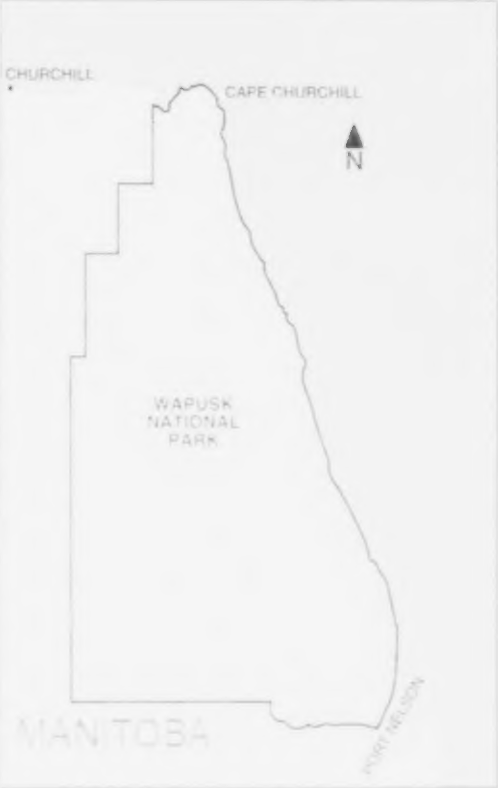

Figure 12-2. Wapusk National Park (adapted from New Parks North, March 1997).

Figure 12-3. Ukkusiksalik National Park (Wager Bay) (adapted from New Parks North, March 2003).

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12.1.2 Marine

Parks Canada has identified nine marine regions in arctic Canada within which it plans to identify Natural Areas of Canadian Significance (NACS). The National Marine Parks Policy guides this process (Canada 1986). Each area is intended to represent the natural, historical, and cultural diversity within a region. While National Marine Parks have yet to be established in northern Canada, Parks Canada has sought advice on which areas might make the best and most representative marine park in the James Bay, Hudson Bay and Hudson Strait marine regions, which lie entirely or partially within the Hudson Bay marine ecosystem (Figure 12-4). Their boundaries were drawn on the basis of physical and biological oceanography (Dunbar 1988).

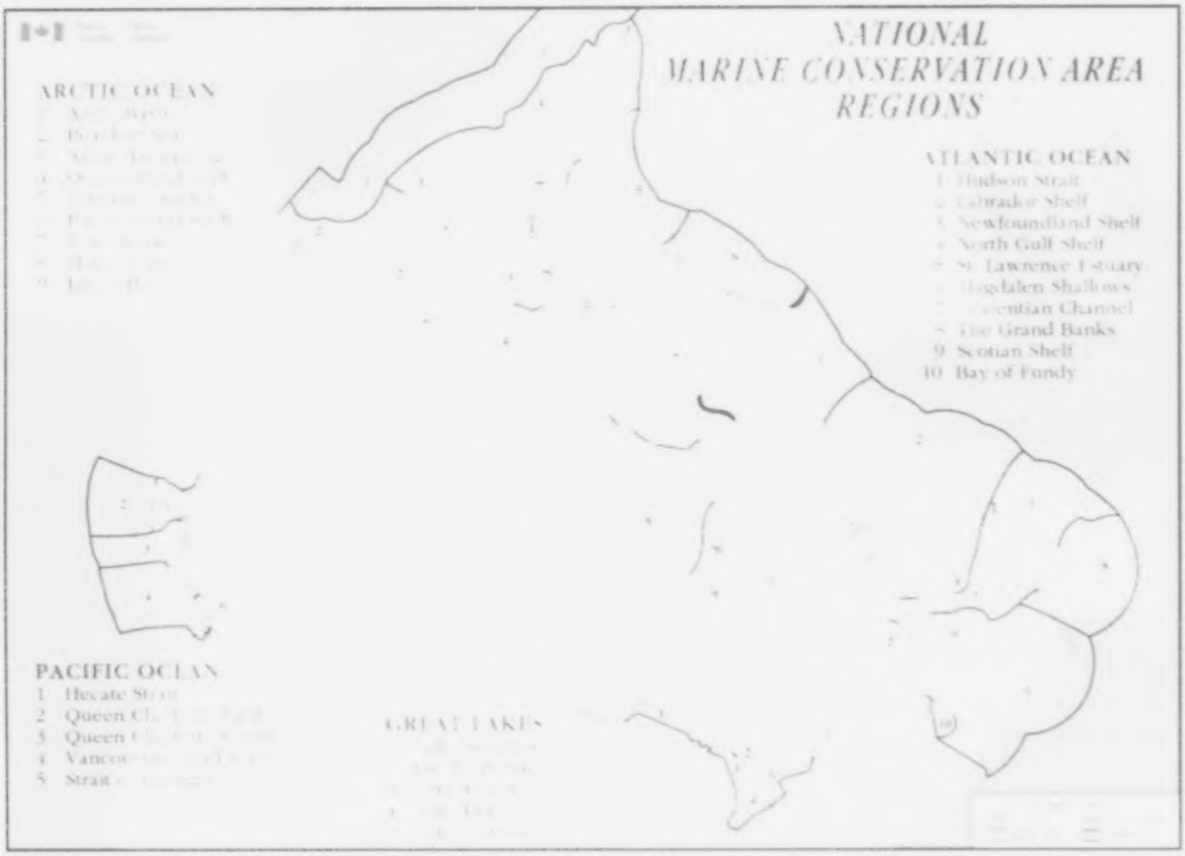

Figure 12-4. Arctic marine regions delineated by Parks Canada (courtesy F. Mercier, CPS Hull, pers. comm.).

James Bay

There is no single area of moderate size within the James Bay marine region wherein the characteristic regional marine features are represented adequately. Consequently, Stewart et al. (1993) recommended that each of the four distinctive areas in the James Bay marine region be represented in Canada's system of National Marine Parks, either by individual marine parks or by a composite marine park consisting of four non-contiguous areas as provided for under the National Marine Parks Policy (see Canada 1986, Section 1.2.3). The areas recommended for consideration were: Chickney Point in western James Bay, the Rivière du Castor estuary in eastern James Bay, Richmond Gulf (Lac Guillaume-Delisle) in the Hudson Bay Arc, and the Belcher Islands. Each of these areas presents features that are not found elsewhere in Arctic Canada, so that none of them can

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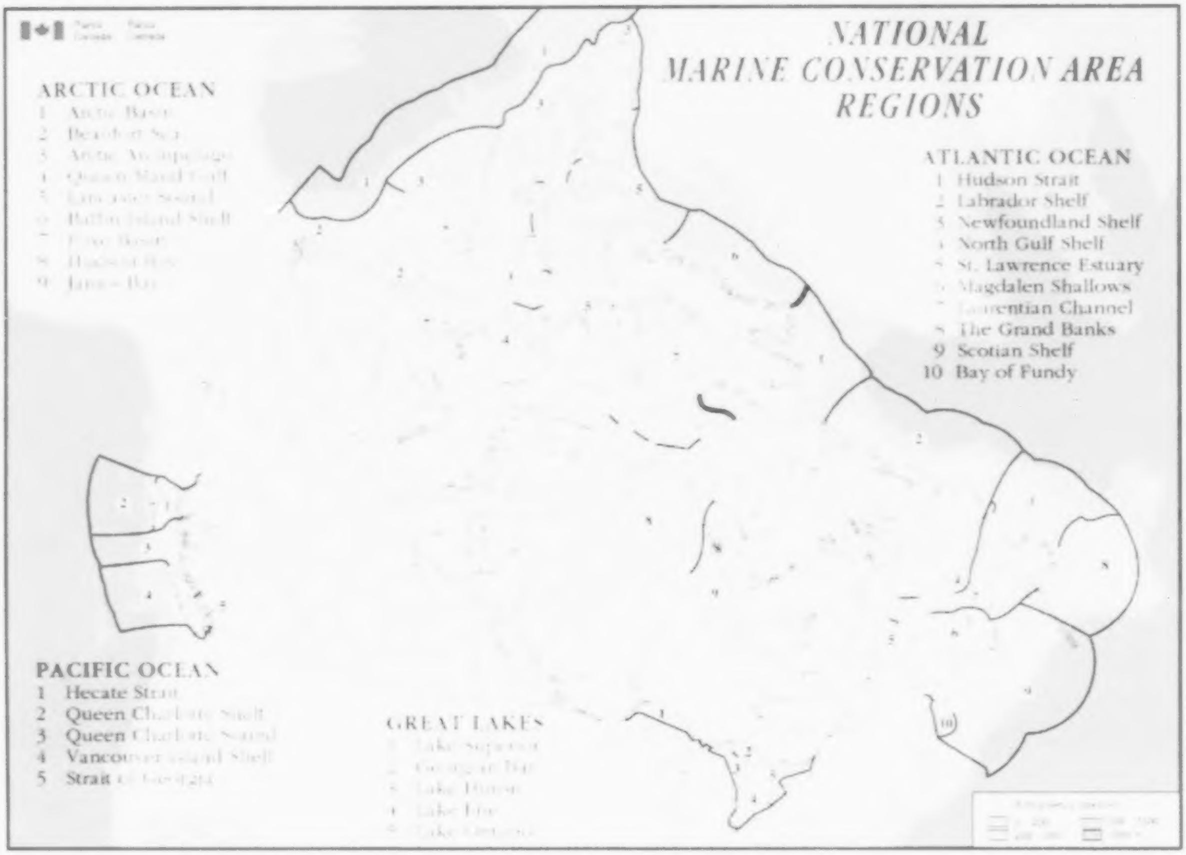

Figure 12-4. **Arctic marine regions delineated by Parks Canada (courtesy F. Mercier, CPS Hull, pers. comm.).**

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Western James Bay offers some of the finest examples of a fast-emerging, shallow coastline and its extensive salt marshes and tidal flats provide shorebird and waterfowl habitats of critical national and international importance. Along the western James Bay coast, the areas of greatest value to shorebirds, north and south of the Albany River, have not yet been afforded any statutory protection (Gillespie et al. 1991). Chickney Point, north of the Albany River, is one of the most important areas for shorebirds in the Hudson Bay Lowlands, and is of critical international importance to the Hudsonian godwit, which appears to make a non-stop flight from its staging grounds in James Bay to wintering areas in South America (see Appendix 4 for scientific names of birds). The very large concentrations of Hudsonian godwit and other species at Chickney Point are very noteworthy (Curtis and Allen 1976). Ontario (OMNR 1985) also considers the Chickney Point area to be Provincially significant, citing as significant features the "extensive display of coastal tidal/super-tidal marsh and freshwater thicket/meadow marsh" and the waterfowl habitat. The boundaries of the proposed NACS at Chickney Point extend 10 km inshore and 10 km offshore from the high tide mark, between 52°24'N and 52°30'N (Figure 12-5). This area was recommended to protect and preserve the exceptional shorebird habitat at Chickney Point and to present the transitional features of the fast-emerging coastline.

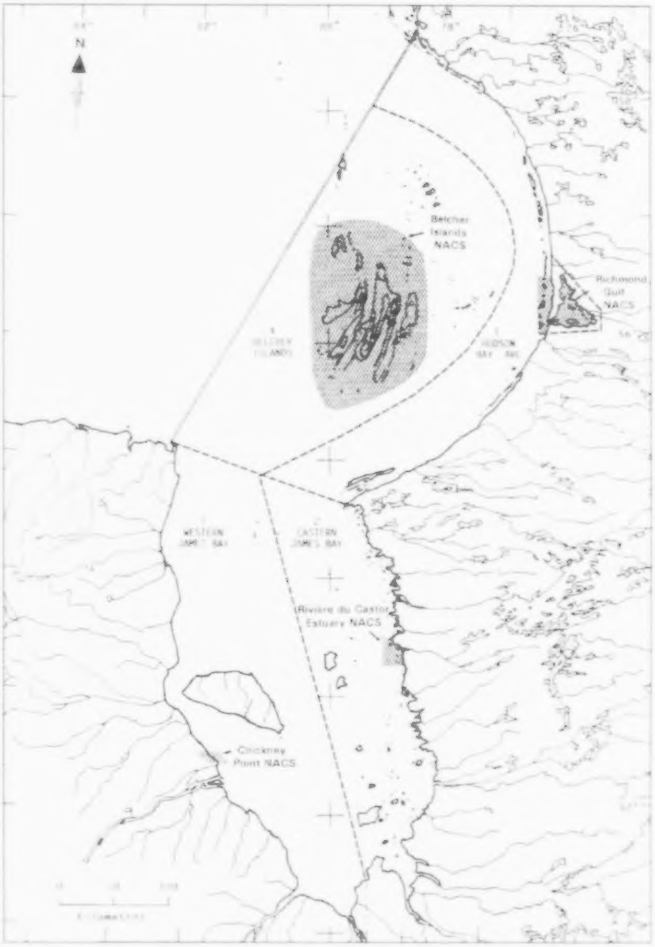

Figure 12-5. **Natural Areas of Canadian Significance (NACS) recommended for consideration as new national marine parks in the James Bay marine region (from Stewart et al. 1993)**

The skerry coastline of the Eastern James Bay area offers a rich variety of coastal and marine habitats. Because the area receives a very large volume of freshwater runoff from the land, unique brackish water communities have developed in its estuaries and coastal waters. These communities include a mixture of Arctic marine, estuarine and freshwater species--some of them relicts. The extensive subtidal eelgrass beds, which are unusual in Canada's Arctic waters and form the base of major food chains in the James Bay marine ecosystem, are particularly noteworthy and of critical international importance for brant. These themes are well represented at the Rivière du Castor estuary (e.g., Curtis 1974/5; Curtis and Allen 1976; SEBJ 1990; Dignard et al. 1991), which was recommended to protect and preserve examples of the area's extensive eelgrass beds, unique brackish water communities, and critical migratory bird habitats. The boundaries of this proposed NACS extend inshore along the Quebec coast to the high tide mark and from 53°15'N near the Comb Islands north to 53°30'N, and offshore to 79°15'W (Figure 12-5). The river has not been altered by hydroelectric development, so that the natural seasonal flow into the estuary has been maintained. It is somewhat removed from the influence of existing and proposed hydroelectric developments, and from the communities of Chisasibi and Wemindji.

The Hudson Bay Arc area is a transitional area wherein the southern brackish features are gradually replaced by Arctic marine features. It offers a number of remarkable marine habitats including the Long Island area, the Nastapoca River estuary with its threatened beluga population, the Nastapoca archipelago, and Lac Guillaume-Delisle (formerly Richmond Gulf). Of these, the enclosed marine environment of Lac Guillaume-Delisle with its spectacular coastline is unique, and least likely to be affected by hydroelectric development. The proposed boundaries of this NACS encompass the whole of Lac Guillaume-Delisle, Gulf Hazard, and the coastal waters and islands of southeastern Hudson Bay bounded on the north by 56°30'N, on the west by 76°50'W, and on the south by 56°00'N (Figure 12-5). The main purpose of the latter would be to include the small polynya at Gulf Hazard and some representative coastal habitats of southeastern Hudson Bay proper. There are few "hard" marine data to support or oppose the consideration of Lac Guillaume-Delisle as a NACS so the recommendation was based on a sense that this enclosed ecosystem is unique and worthy of preservation. It does support a rich fauna that includes Arctic marine, estuarine, and freshwater species--some of them relicts. The coastline is spectacular, with cuestas and flights of raised marine beaches, and at Gulf Hazard there are important archaeological sites and winter open water. Much of the land surrounding Richmond Gulf is Inuit owned.

The Belcher Islands area, virtually unknown until this century, is also unique--not so much for its individual features as for the whole. It offers a relatively rich marine ecosystem that supported, and continues to support, a specialized maritime culture. The archipelago has a remarkably rich avifauna that includes an indigenous population of Hudson Bay eider that is resident year-round. No specific area of the Belchers was recommended for consideration as a NACS, as scientific information was insufficient for the purpose and the question is better considered by direct consultation between Parks Canada and the Belcher Islands Inuit who, under the Nunavut Land Settlement, have wide and well-defined rights relating to the use of coastal and offshore areas of the archipelago. The purpose of this NACS would be to preserve and protect at least a representative cross-section of marine habitats in the Belcher Islands area, in particular those related to walrus and the indigenous subspecies of the common eider (Figure 12-5).

Political jurisdictions and economic factors were not considered in these boundary recommendations, only those factors that contribute significantly to the character of the James Bay marine region. Areas that already had statutory protection such as the Twin Islands, Akimiski Island, Boatswain Bay, and Hannah Bay were considered but were not included in the NACS. They offer important migratory bird habitats and characteristic coastal features which complement but cannot replace those of the recommended NACS.

Hudson Bay

Unlike James Bay, the characteristic features of the Hudson Bay marine region can be well represented in a single area. Stewart et al. (1991) recommended two areas of this region to Parks Canada for consideration as national marine parks, the Churchill-Nelson area and the Rankin Inlet-Marble Island area.

The Churchill-Nelson area was recommended as the logical choice for a marine park in the region. It encompasses an area of Hudson Bay bounded in the north by 59°30'N latitude, in the east by 91°00'W longitude, and to the south and west by the Manitoba coast (roughly from Cape Tatnam in the east to Hubbert Point in the west)--inland to the high tidal marks (Figure 12-6). The intent of a marine park in this geological and cultural transition zone would be to protect and preserve the exceptional beluga population that summers there, and to include the widest possible variety of coastal, seafloor, and oceanographic conditions and habitats.

Characteristic themes of the Hudson Bay marine region that are particularly well represented in this area include: 1) the extensive low-lying marshy coastal plains with wide tidal mud flats; 2) large estuaries of the Churchill and Nelson rivers; 3) exceptional summer concentrations of belugas in the estuaries of the Nelson, Churchill, and Seal rivers 4) exceptional autumn concentrations of polar bears on the islands and headlands near Cape Churchill; 5) breeding shorebirds and waterfowl including Hudsonian godwit and the Hudson Bay subspecies of the common eider; and, 6) prehistorical coastal cultures, historical ports of entry instrumental in the exploration and development of central Canada, and the region's only deep water port for international shipping.

This area was recommended before Wapusk National Park was established. It would complement the existing park by protecting the largest concentration of belugas in the world and offer a relatively accessible area for presenting other Arctic marine features.

The Rankin Inlet-Marble Island area extends inshore to the high tide mark along the Kivalliq coast from 62°35'N near Cape Jones north to 63°00'N, and offshore to 89°00'W (Figure 12-6). This area would afford protection to the exceptional peregrine falcon population and the maritime historical sites at Marble Island and include a wide variety of coastal, seafloor, and oceanographic conditions and habitats.

Characteristic themes of the Hudson Bay marine region that are particularly well represented in this area include: 1) anadromous Arctic charr; 2) a dense breeding population of threatened peregine falcon near Rankin Inlet, and a breeding colony of the Hudson Bay subspecies of the common eider on Marble Island; 3) evidence of prehistorical coastal Inuit cultures; and 4) historical sites from the Knight Expedition and whaling period, including two accessible shipwrecks.

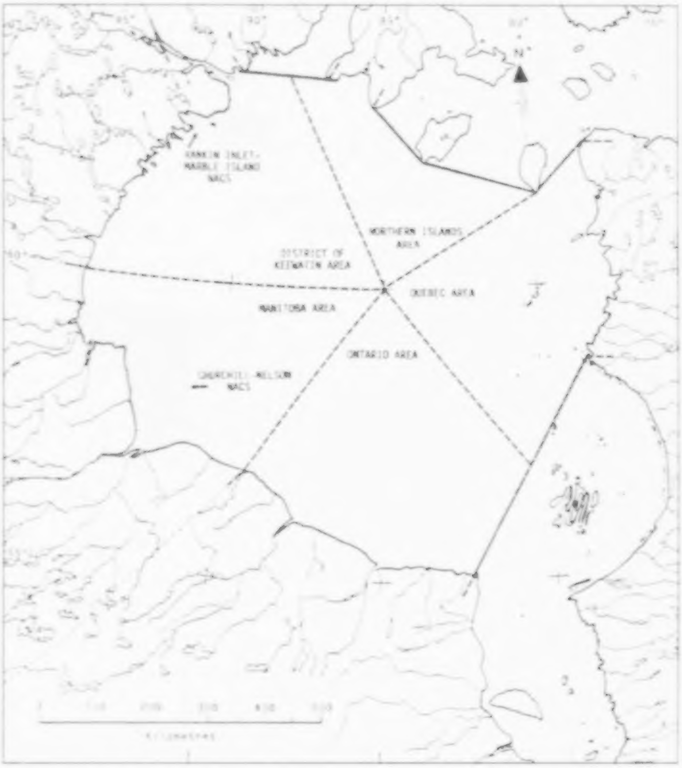

Figure 12-6. **Natural Areas of Canadian Significance (NACS) recommended for consideration as new national marine parks in the Hudson Bay marine region (from Stewart et al. 1991).**

Both the exceptional peregrine population and the maritime historical sites at Marble Island are facing increasing human disturbance. They are located near the growing community of Rankin Inlet and Marble Island is a stop for tourists visiting by cruise ship. Both of areas would benefit immediately from the protection afforded by National Parks designation.

The area's rocky, Shield coasts are less representative of the region but provide a greater variety of coastal and nearshore marine habitats than the Churchill-Nelson area. The Diana and Meliadine rivers provide small-scale estuarine habitats, and there is greater arctic character and better representation of typically arctic conditions, species, and cultures than the Churchill-Nelson area. Landfast sea ice is well represented, and the plume from Chesterfield Inlet also influences the area oceanographically. Access to the region is, however, more limited.

While this area would afford some protection to historical bowhead habitats, a larger area stretching from the northwestern boundary of the Hudson Bay marine region along the west coast of Roes Welcome Sound north to about 59°30'N and extending part way across the sound would be more effective.

Hudson Strait

The area of Hudson Strait immediately northeast of the Hudson Bay marine region was recommended as the most representative candidate for consideration as a future national marine park in the Hudson Strait marine region (Mercier 1991). However, this was before its boundaries were altered to include Foxe Basin and exclude eastern Hudson Strait, as shown in Figure 12-4. Habitats and features of the Repulse Bay and Wager Bay areas were not considered to be representative of the marine region as a whole. However, protection of the waters of Wager Bay within any new National Park in the Wager Bay area was recommended, and has been legislated (see Section 12.1.1).

12.2 PROVINCIAL AND TERRITORIAL PARKS

12.2.1 Quebec

Two areas of northern Quebec that include portions of the Hudson Bay coast are currently under consideration as possible future parks. The first area encompasses Lac Guillaume-Delisle (formerly Richmond Gulf) and Lac à l'Eau-Claire, which drains into it via Rivière à l'Eau Claire (Figure 12-1) ([illegible]). The area under study is located in the transition zone between boreal forest and tundra and covers about 10,290 km^2. Lac Guillaume-Delisle (56°15'N, 76°17'W) is a marine embayment connected to Hudson Bay by a narrow channel. It is subject to tides and supports marine biota including seals and belugas. The shoreline is remarkable for its high cuestas. This area has also been studied as a possible National Park (McNicholl 1990) and suggested for consideration as a National Marine Park (Stewart et al. 1993). Lac à l'Eau-Claire (56°10'N, 74°25'W) is the second largest freshwater lake in Quebec and fills the impact basin created by two meteors. Together, the Makivik Corporation, the Kativik Regional Government, and the Government of Québec plan to create a new park in this region by 2007.

The second area encompasses the Puvirnituq Mountains, which extend inland northeastward from Akulivik ([illegible]). This proposal is less advanced. Studies are planned to assess the state of knowledge of an area of about 3,000 km^2.

The area northeast of Cape Wolstenholme, at the northern most tip of Quebec is also under consideration ([illegible]). This area, which borders Hudson Strait, includes a massive colony of thick-billed murres.

12.2.2 Ontario

Polar Bear Provincial Park

This 2,355,200 ha wilderness park extends eastward along the coast of Hudson Bay from 87°W to Cape Henrietta Maria and then south along the James Bay coast to 54°N (Figure 12-7). It is the largest and most northerly park in Ontario and features some of Canda's most southerly tundra and a vast wetland complex. The park has an IUCN designation of 2, which signifies that it is designed to protect a relatively large natural area of national or international significance that has not been materially altered by human activity, and where extractive resource uses are not allowed. Polar Bear Provincial Park is notable for its Arctic wildlife, including polar bears and walruses, and its seasonal use by migratory waterfowl and shorebirds.

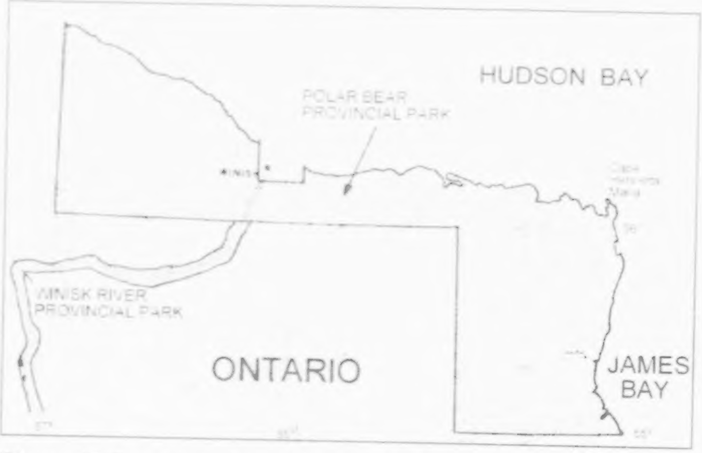

Figure 12-7. **Polar Bear Provincial Park in Ontario (adapted from OMNR 1985).**

During migration, the area supports hundreds of thousands of migratory waterfowl, including a substantial portion of the central Arctic breeding population of the red knot, the entire breeding population of the Hudsonian godwit, and over a million Canada geese. There is also a breeding colony of over 50,000 Canada geese. The park was designated as a Ramsar site (no. 360) in 1987 because of the importance of its wetlands to migratory birds. (http://www.ontarioparks.com/english/pola.html)

Kesagami Provincial Park

This 55,977 ha wilderness park follows the Kesagami River for about 80 km through the James Bay lowlands until it drains into the Hurricanaw River immediately upstream of the southern tip of James Bay (Figure 12-1). It too has an IUCN designation of 2. There is a commercial lodge in the park and canoeing, camping, and fishing are permitted. (http://www.ontarioparks.com/english/kesa.html)

Tidewater Provincial Park

Located on four islands in the Moose River estuary, this 980 ha "natural environment" park is about 20 km upstream from James Bay (Figure 12-1). It is accessible by water taxi from Moosonee and notable for its subarctic flora and fauna, and as the historical site of the first Hudson's Bay Company trading post at Moose Factory.

Winisk River Provincial Park

This 141,000 ha park is a wilderness whitewater river. The river passes through a large moraine and drumlin field on its way to Hudson Bay (Figure 12-7). It has an IUCN designation of 2. There are no visitor facilities.

12.2.3 Manitoba

There are no provincial parks in Manitoba that extend to the Hudson Bay coast. However, two coastal wildlife management areas (WMA), the Cape Tatnam WMA and the Cape Churchill WMA have been established to protect the region's coastal and tundra ecosystems. The latter once included the area now protected by Wapusk National Park, but now includes only land to the south and west (Figure 12-8).

(http://www.gov.mb.ca/conservation/wildlife/managing/wma_northeastern.html - cape_tatnam)

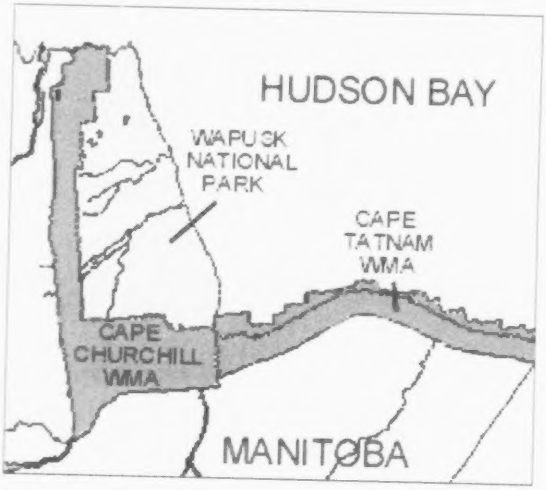

Figure 12-8. Cape Churchill and Cape Tatnam Wildlife Managment Areas in Manitoba.

12.2.4 Nunavut

Territorial Parks in Nunavut are selected to reflect what is most important to Nunavummiut. They are developed in partnership with communities, in areas people believe to be important and where the people of Nunavut will benefit from them. The Nunavut Department of Sustainable Development (DSD), through the Parks and Tourism Division and the Wildlife and Fisheries division, manages these parks. (http://www.nunavutparks.ca/parks_planning/index.cfm)

Ijiraliq Territorial Park

This small territorial park straddles the Meliadine River about 10 km northwest of Rankin Inlet (Figure 12-1). It is accessible by rough road from Rankin Inlet and has become a destination for passengers aboard cruise ships visiting western Hudson Bay. The park is notable for its Thule, Dorset, and Pre-Dorset archaeological sites and glacial eskers. The Meliadine Esker that runs parallel to the river is one of the largest, continuous features of its kind. In 1975, it was identified by the International Biological Programme (IBP) as a colony of over 50,000 Canada geese. The park was designated as a Ramsar site (no. 360) in 1987 because of the importance of its wetlands to migratory birds. ([illegible])

Kesagami Provincial Park

This 55,977 ha wilderness park follows the Kesagami River for about 80 km through the James Bay lowlands until it drains into the Harricanaw River immediately upstream of the southern tip of James Bay (Figure 12-1). It too has an IUCN designation of 2. There is a commercial lodge in the park and canoeing, camping, and fishing are permitted. ([illegible])

Tidewater Provincial Park

Located on four islands in the Moose River estuary, this 980 ha "natural environment" park is about 20 km upstream from James Bay (Figure 12-1). It is accessible by water taxi from Moosonee and notable for its subarctic flora and fauna, and as the historical site of the first Hudson's Bay Company trading post at Moose Factory.

Winisk River Provincial Park

This 141,000 ha park is a wilderness whitewater river. The river passes through a large moraine and drumlin field on its way to Hudson Bay (Figure 12-7). It has an IUCN designation of 2. There are no visitor facilities.

12.2.3 Manitoba

There are no provincial parks in Manitoba that extend to the Hudson Bay coast. However, two coastal wildlife management areas (WMA), the Cape Tatnam WMA and the Cape Churchill WMA have been established to protect the region's coastal and tundra ecosystems. The latter once included the area now protected by Wapusk National Park, but now includes only land to the south and west (Figure 12-8).

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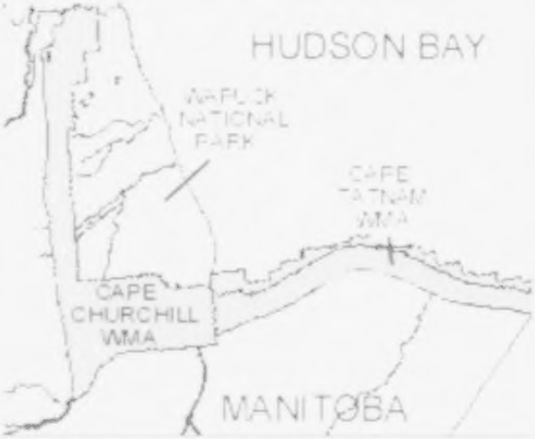

Figure 12-8. **Cape Churchill and Cape Tatnam Wildlife Managment Areas in Manitoba.**

12.2.4 Nunavut

Territorial Parks in Nunavut are selected to reflect what is most important to Nunavummiut. They are developed in partnership with communities, in areas people believe to be important and where the people of Nunavut will benefit from them. The Nunavut Department of Sustainable Development (DSD), through the Parks and Tourism Division and the Wildlife and Fisheries division, manages these parks. ([illegible])

Ijiraliq Territorial Park

This small territorial park straddles the Meliadine River about 10 km northwest of Rankin Inlet (Figure 12-1). It is accessible by rough road from Rankin Inlet and has become a destination for passengers aboard cruise ships visiting western Hudson Bay. The park is notable for its Thule, Dorset, and Pre-Dorset archaeological sites and glacial eskers. The Meliadine Esker that runs parallel to the river is one of the largest continuous features of its kind. In 1975, it was identified by the International Biological Programme (IBP) as a feature worthy of protection (Nettleship and Smith [ed.] 1975). The Meliadine River supports a run of anadromous Arctic charr and has been the site of an important Inuit fishery (McGowan 1992).

([illegible])

12.3 MIGRATORY BIRD SANCTUARIES

The Canadian Wildlife Service (CWS) of Environment Canada establishes bird sanctuaries to control and manage areas of importance for the protection of migratory birds, their nests, and eggs. These sanctuaries can include a range of habitat types, such as terrestrial, wetland, or marine. The CWS establishes regulations determining what activities can be carried out within these areas. Prohibited activities include the harassment or killing of birds, and disturbing, destroying, or possessing nests or eggs.

Under the Nunavut Land Claims Agreement (NLCA) an Inuit Impact and Benefit Agreement (IIBA) must be negotiated for most conservation areas, including existing Migratory Bird Sanctuaries, and a managment plan must be prepared for all of them. The East Bay Migratory Bird Sanctuary on southeastern Southampton Island lies just outside the boundaries of the Hudson Bay marine ecosystem, as does Digges Island which is under study as a possible bird sanctuary. The CWS has identified both areas as key terrestrial migratory bird habitat (Alexander et al. 1991). Digges Island has also been identified as an IBP site (Nettleship and Smith [ed.] 1975).

([illegible])

([illegible])

12.3.1 Boatswain Bay Bird Sanctuary

This sanctuary lies just north of Rupert Bay in southeastern James Bay (Figure 12-9). It includes all waters and lands in Boatswain Bay and all land 3 km inland from the high-tide mark (Alexander et al. 1991). The offshore islands and reefs lie within Nunavut and the coastline in Quebec. This area is very important for a variety of migrating and moulting water birds including Canada geese, lesser snow geese, Atlantic brant, American black ducks, northern pintails, scoters, scaups, and several species of shorebirds (Curtis and Allen 1976).

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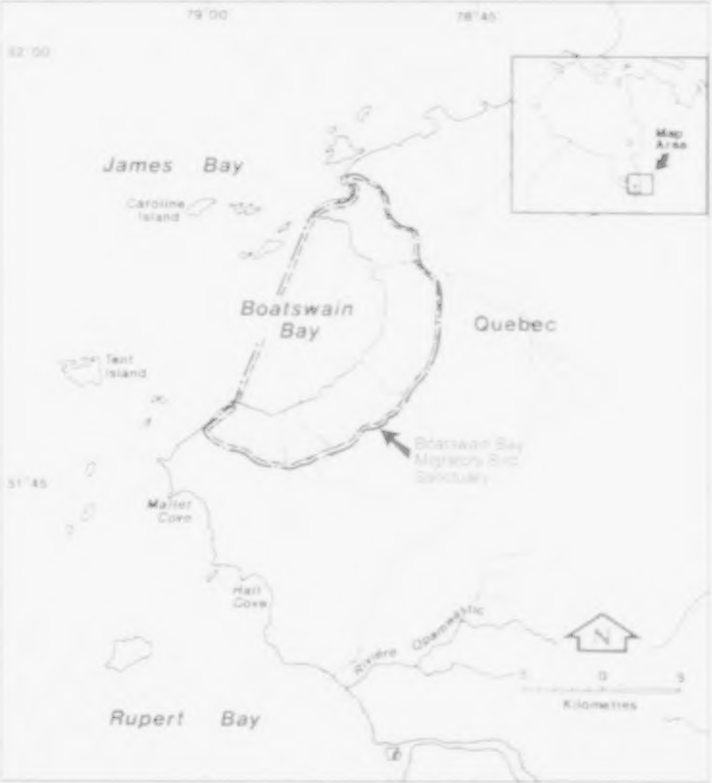

Figure 12-9. Boatswain Bay Migratory Bird Sanctuary (adapted from Alexander et al. 1991, p. 170).

12.3.2 Hannah Bay Migratory Bird Sanctuary

This small sanctuary has one of the widest expanses of marsh along the James Bay coast. It lies at the entreme southern tip of the bay near the Ontario-Quebec border (Figure 12-10). The coast lies in Ontario and the offshore islands and reefs within Nunavut—the latter are part of the James Bay Preserve. The marsh

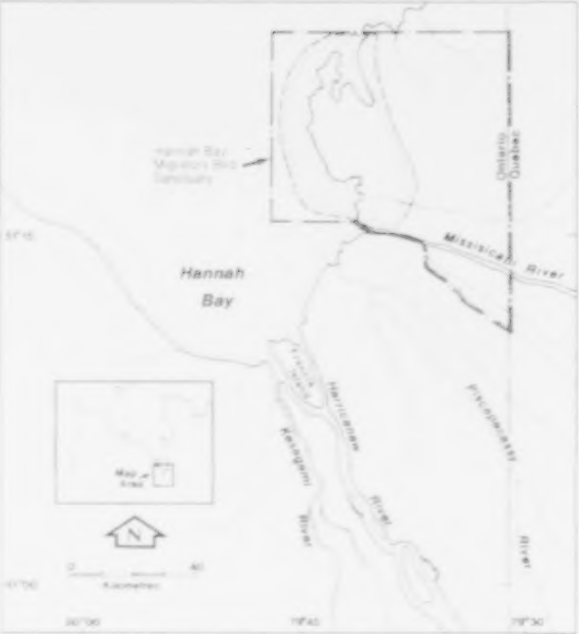

Figure 12-10. Hannah Bay Migratory Bird Sanctuary (adapted from Alexander et al. 1991, p. 172).

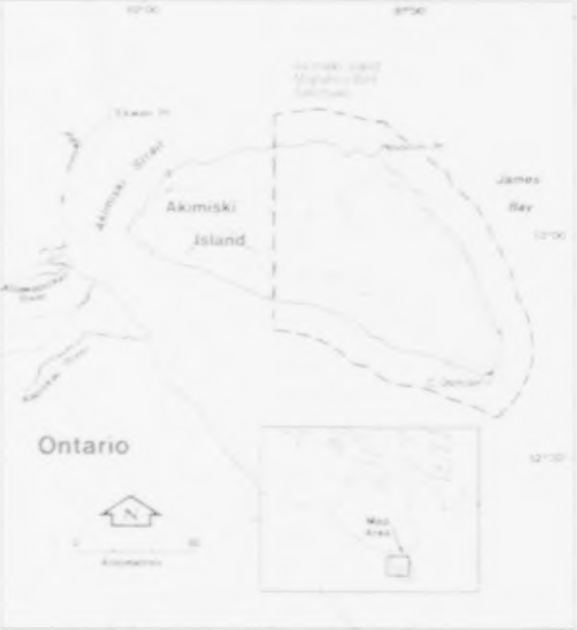

Figure 12-11. Akimiski Island Migratory Bird Sanctuary (adapted from Alexander et al. 1991, p. 168).

averages 1.5 km in width and the adjacent tidal flats 15 km (Alexander et al. 1991). It is one of the most important staging areas in North America for migratory, Arctic-breeding waterfowl—particularly lesser snow geese and Canada geese and shorebirds (Curtis and Allen 1976). Hannah Bay has been identified as key terrestrial habitat for migratory birds by the CWS (Alexander et al. 1991). This sanctuary and the Moose River Migratory Bird Sanctuary constitute the Southern James Bay Migratory Bird Sanctuaries, which were designated as wetlands of international importance in 1987 under the Ramsar Convention (part of site no. 367).

12.3.3 Moose River Migratory Bird Sanctuary

This sanctuary and the Hannah Bay Migratory Bird Sanctuary constitute the Southern James Bay Migratory Bird Sanctuaries, which were designated as wetlands of international importance in 1987 under the Ramsar Convention (part of site no. 367). The site extends along the Ontario coast of James Bay north and east from the mouth of the Moose River, for about 10 km in each direction and includes Ship Sands Island, which is located on the northern side of the river's mouth. Like Hannah Bay, to the east, its wide tidal mudflats (1 km), intertidal marsh, meadow marsh, fens, and bogs provide important staging habitat, primarily in the late fall, for large numbers of lesser snow geese, Canada geese, and dabbling ducks. The area is also heavily used in the spring by returning dabbling ducks.

([illegible])

12.3.4 Akimiski Island Migratory Bird Sanctuary

This sanctuary takes up the eastern two-thirds of Akimiski Island in west central James Bay and is part of the James Bay Preserve (Figure 12-11). It is a critical staging and/or moulting area for migratory waterfowl and shorebirds, particularly lesser snow geese, Atlantic brant, Caspian terns, red knots, Hudsonian godwits and semipalmated plovers. Significant numbers of Canada geese and lesser snow geese nest on the island. The Canadian Wildife Service has identified most of the coastline as key terrestrial habitat for migratory birds (Alexander et al. 1991). Northern Akimiski Island is also a summer retreat and maternity denning area for polar bears (Jonkel et al. 1976).

[illegible]

12.3.5 McConnell River Migratory Bird Sanctuary

This 32,800 ha sanctuary was established in 1960 to protect a small colony of lesser snow geese (Figure 12-12). It is located south of Arviat on the Nunavut coast of Hudson Bay and is protected under the Migratory Bird Sanctuary Regulations that stem from the Migratory Birds Convention Act of 1917. The site is owned by the Inuit of Nunavut and is subject to co-management agreements under the Nunavut Land Claims Agreement. Inuit from Arviat continue to hunt, trap, and fish within the sanctuary. The area identified in 1975 as an IBP site in need of protection was somewhat larger than the existing sanctuary (Nettleship and Smith [ed.] 1991). The sanctuary boundaries are under review and may increase as most geese now nest, moult, and graze outside the sanctuary (CWS 1990).

In 1982, the sanctuary was designated as a "Wetland of International Importance especially as Waterfowl Habitat" under the terms of the Ramsar Convention (Ramsar site 248). It received this designation because the area is a major summer nesting habitat for several species of migratory birds, including lesser snow goose, Ross's goose, and Canada goose. Up to 200,000 birds colonize this site annually and habitat degradation is occurring due to an increase in the snow goose population. The Canadian Wildlife Service has identified this area as key terrestrial migratory bird habitat (Alexander et al. 1991).

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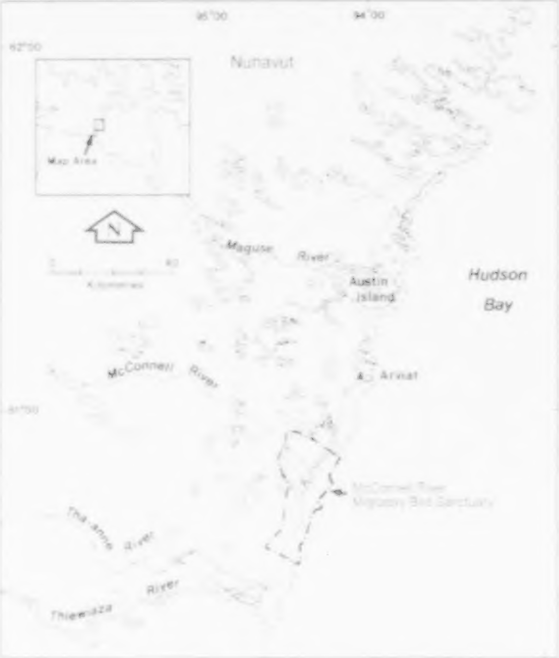

Figure 12-12. McConnell River Migratory Bird Sanctuary and the extent of the key terrestrial habitat for the snow goose colony (adapted from Alexander et al. 1991, p. 54).

12.3.6 Harry Gibbons Migratory Bird Sanctuary

This sanctuary is located in northern Hudson Bay on Southampton Island, where it extends about 35 km inland from Bay of Gods Mercy to encompass low-lying wetland habitats and extensive tidal flats around the mouth of the Boas River (Figure 12-13). The river delta supports a nesting colony of lesser snow geese that was estimated at 529,100 birds in 1997, and nesting populations of Atlantic brant, Canada geese, and tundra swans. Smaller breeding colonies are located outside the sanctuary at Ell Bay and Bear Cove. The CWS has identified the Boas River area as key terrestrial migratory bird breeding habitat (Alexander et al. 1991); it is also an IBP site (Nettleship and Smith [ed.] 1975).

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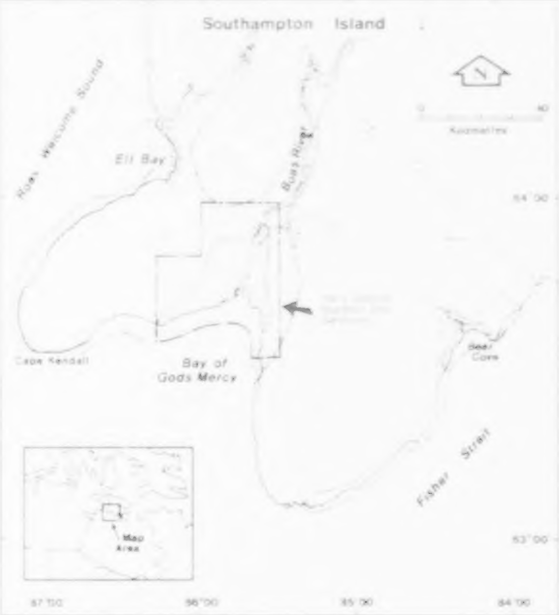

Figure 12-13. Harry Gibbons Migratory Bird Sanctuary (adapted from Alexander et al. 1991, p. 130).

12.4 TERRITORIAL GAME SANCTUARIES

Territorial game sanctuaries protect wildlife species and their habitat while preserves protect wildlife for the benefit of native hunters and trappers (New Parks North, March 1998). The James Bay Preserve includes the islands and shoals of James Bay, which are part of Nunavut. Some of these islands have key migratory bird habitats that have been afforded greater protection either as migratory bird sanctuaries managed by CWS or as territorial game sanctuaries managed by the Government of Nunavut.

12.4.1 Twin Islands Game Sanctuary

These two small, low-lying islands are situated in central James Bay (Figure 12-14). They are part of the James Bay Preserve (Alexander et al. 1991) and were identified as an IBP site (Nettleship and Smith [ed.] 1991). The islands are an important summer sanctuary and winter denning area for polar bears. They have also been identified tentatively by CWS as key terrestrial habitat for migratory birds (Alexander et al. 1991). An estimated 23,600 birds of various species may nest on the islands.

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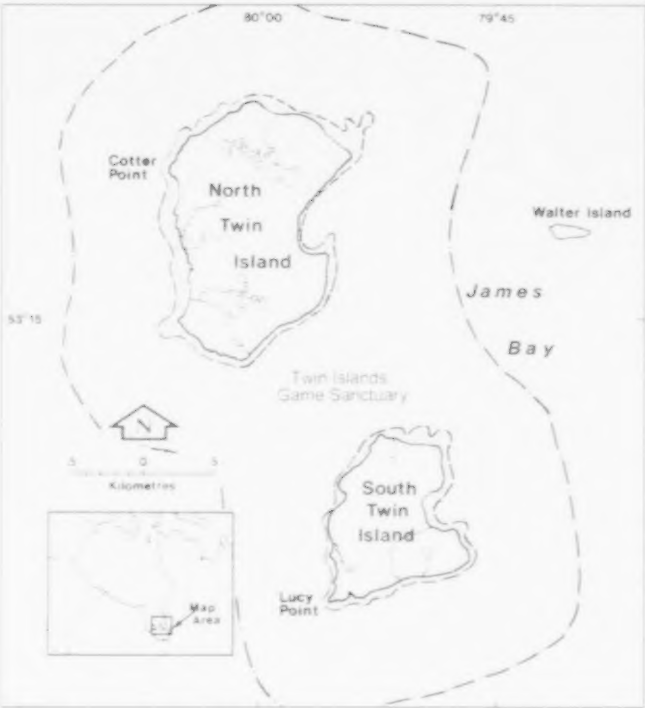

Figure 12-14. Twin Islands Game Sanctuary (adapted from Alexander et al. 1991, p. 164).

12.5 NATIONAL HISTORIC SITES

Parks Canada administers a program that recognizes places of national historic importance. These sites and their associated artifacts are preserved to promote an appreciation of historic places, people, and events and their contribution to the Canadian identity. Several of these sites are located in coastal areas of Hudson Bay and each of these has been important in the region's maritime history.

12.5.1 York Factory

The Hudson Bay Company built the original fur trading post at York Factory in 1684, near the mouth of the Hayes River on the Manitoba coast. This location was chosen because it was accessible to ocean-going vessels, which would anchor at Five Fathom Hole, and provided a safe harbour. Trade goods were transferred from the ships to York Factory, and then carried inland via navigable rivers in smaller boats. York Factory served as a major administrative, transshipment, and manufacturing centre within the company's fur trade network for over 250 years. It afforded the company good access to the good quality furs of the hinterland and to existing aboriginal trade networks.

The 102 ha national historic site includes the Hudson's Bay Company's Depot building, a clearing around it, and some marsh and boreal/taiga forest cover. The current building, known as York Factory III, was developed after 1788 and abandoned by the Hudson's Bay Company in 1957. The sites of the two earlier buildings have been destroyed by erosion of the north bank of the Hayes. The site commemorates York Factory for its critical role in the French-English struggle for control of the fur trade, for its long and important role as a trading post and distribution centre, and for its role in the expansion of the fur trade into the interior of western Canada. ([illegible])

12.5.2 Prince of Wales Fort

The Hudson Bay Company began building this massive stone fort at the mouth of the Churchill River in 1731 but it was not completed until 1746. The location offered a better harbour than York Factory and was a likely site for a whaling operation (Payne 1978-9). The fort was a hundred yards square and had more cannons (42) than men. Unfortunately, it was not strategically placed or manned to withstand an assault from the sea, and was surrendered without resistance by Samuel Hearne to Comte de la Perouse in 1782 (Rich 1958; Mathews 1966). Today the partially restored fort is a national historic site that commemorates the role of Prince of Wales Fort in the 18th-century French/English rivalry for control of the territory and resources around Hudson Bay. The site also includes the Cape Merry Battery on the opposite shore of the river and the harbour at Sloop Cove.

([illegible])

12.5.3 Arvi'juaq National Historic Site

Arvia'juaq (Sentry Island) and Qikiqtaarjuk, near Arviat, were designated as a national historic site in August 1995 (Figure 12-15). For centuries Inuit returned each spring to camp at these locations and to harvest the abundant marine resources. These gatherings also provided an opportunity to teach the young, celebrate life, and to affirm and renew Inuit society. The island was first ocupied about 1200AD and has some 117 archaeological sites (Travel Keewatin 1990). One site is thought to be a beluga hunting/caribou crossing hunting game. It consists of stone outlines of kayaks, shorelines, and other features and the object was apparently to hone hunting skills. Hunters placed themselves inside the stone kayak outlines while someone pulled a rope with a small loop on the end from one end of the site to the other. If a hunter managed to get the point of his harpoon through the loop, he "got the whale".

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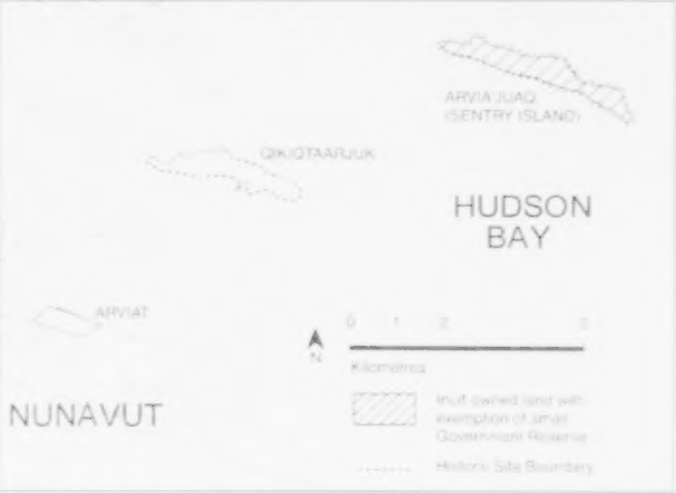

Figure 12-15. **Arvi'juaq National Historic Site (adapted from New Parks North, March 1998).**

12.6 HERITAGE RIVERS

The Canadian Heritage Rivers System (CHRS) is a cooperative program between the parks administrations of the federal and provincial/territorial governments. It was established in 1984 to give national recognition to important rivers in Canada and to ensure that they are managed in a manner that conserves their distinctive value while enhancing public use and enjoyment. Governments nominate rivers, and rivers in this system are outstanding in terms of their human or natural history, or recreational value. The Seal River in Manitoba is the only Canadian Heritage River that drains directly into the Hudson Bay marine ecosystem. Two other rivers, the Hayes in Manitoba ([illegible]; Dodds 1987) and the Missinaibi in Ontario ([illegible]) have been nominated for heritage river status. The Missinaibi drains into the Hurricanaw River, just upstream of James Bay. In Nunavut, the Kazan (http://www.newparksnorth.org/kazan.htm) and Thelon (http://www.chrs.ca/Rivers/Thelon/Thelon-F_e.htm) rivers also have heritage river status but they drain into Baker Lake, well upstream of the marine *ecosystem*.

12.6.1 Seal River

The Seal River was designated as a Canadian Heritage River in 1992, is the largest remaining undammed river in northern Manitoba (Dodds 1986, 1990) (Figure 12-1). It flows some 260 km from its headwaters at Shethanei Lake, through the wilderness transitional zone between subarctic boreal forest and arctic tundra, to Hudson Bay. Its valley exhibits some striking glacial landforms and provides habitat for 33 species of plants that are rare in Manitoba. It also provides winter range for part of the Kamanuriak caribou herd. Harbour seals penetrate well upstream and inhabit the river year-round. Belugas concentrate in the estuary in summer in large numbers.

(http://www.sealriver.com/SealRiverSystem.pdf)

(http://www.chrs.ca/Rivers/Seal/Seal_e.htm)

12.7 SENSITIVE HABITATS

Various programs have identified sensitive, important habitats in the region. Two international programs that deserve special mention are the Ramsar Convention and the International Biological Programme (IBP).

The Convention on Wetlands of International Importance especially as Waterfowl Habitat (Ramsar Convention) was adopted in Ramsar, Iran, in 1971, and came into force in Canada in 1981 (Gillespie et al. 1991) (see also (http://www.ramsar.org/profiles_canada.htm). Ramsar seeks to ensure the sustainable, wise use of wetland resources including designation of wetland sites of international importance, and to ensure that all wetland resources are conserved, now and in the future. In Canada, the Canadian Wildlife Service (CWS) in cooperation with the provinces and territories is responsible for identifying and describing sites worthy of inclusion in the Ramsar List of Wetlands of International Importance, and for ensuring that they are given adequate legislative protection. To date, four Ramsar sites have been identified along the coast of the Hudson Bay marine ecosystem and at least part of each of these wetlands is now protected. This protection is afforded by the McConnell River, Hannah Bay, and Moose River Migratory Bird Sanctuaries and by Polar Bear Provincial Park.

In 1975, the International Biological Programme (IBP) recognized a number of areas of biological, geological, and historical importance in northern Canada that were in urgent need of special protection (Nettleship and Smith [ed.] 1975). Some of these areas lie within or adjacent to the Hudson Bay marine ecosystem. Areas that have since been afforded protection are discussed above. They include the McConnell River (McConnell River Migratory Bird Sanctuary), Twin Islands (Twin Islands Game Sanctuary), and the Boas River (Harry Gibbons Migratory Bird Sanctuary). Areas that were identified but have not yet been protected include the Belcher Islands, Duke of York Bay, the Manitounuk Islands, and Long Island. The latter two areas were identified primarily on the basis of their physiographic features. Coats Island and Digges Sound, which lie just north of the ecosystem boundary, were also identified as IBP sites and key terrestrial habitats for migratory birds. The latter is being considered as a possible bird sanctuary.

The Belcher Islands were selected as an IBP site on the basis of a number of exceptional features, in particular the southerly presence of Arctic flora, endemic population of Hudson Bay eiders, varied marine mammals populations, and archaeological sites (Nettleship and Smith [ed.] 1975). The area has also been recommended for consideration as a new national marine park (Stewart et al. 1993). The CWS has also identified the North Belcher Islands as key terrestrial habitat for birds on the basis of the large nesting colonies of Hudson Bay eiders (Alexander et al. 1991).

Duke of York Bay is in a geological transition zone and offers a wide variety of habitats (Nettleship and Smith [ed.] 1975). It supports a variety of marine mammals and has archaeological sites including some from the recently extinct Sadlermiut Inuit.

The Canadian Wildlife Service has also identified key terrestrial (Alexander et al. 1991) and marine (Mallory and Fontaine 2004) habitats for migratory birds that have not been protected. The terrestrial areas include the Salikuit, Sleeper, and Koktac River archipelagos, which support indigenous populations of Hudson Bay eiders, and northeastern James Bay, which is extremely important for waterfowl including tundra swans, Canada geese, Atlantic brants, and lesser snow geese (see also Dignard et al. 1991; Reed et al. 1996a). Moulting and fall staging dabbling ducks are also very abundant in the latter area (Curtis and Allen 1976; Reed et al. 1996b). The marine areas include waters around the Belcher and Sleeper archipelagos that provide year-round habitat for Hudson Bay eiders (see also Nakashima and Murray 1988; MacDonald et al. 1997; Robertson and Gilchrist 1998; Gilchrist and Robertson 1999, 2000), and along the Ontario coast that provide important moulting habitat for black scoters (see also Ross 1983, 1994).

The marine parks studies have recommended a number of other areas for protection, in particular the estuaries of the Churchill and Nelson rivers for their remarkable concentrations of belugas, and the Rankin Inlet area for its exceptionally dense coastal breeding population of threatened peregrine falcon (Stewart et al. 1991). To this might be added two other "hotspots" of marine activity, one is the area of Hudson Bay north of Churchill where many polar bears concentrate in the winter to hunt seals (Figure 9-8; Stirling et al. 1999). The other encompasses northern Hudson Bay and western Hudson Strait, an area that supports a rich variety of Arctic marine species and was historically an important area for bowhead whales (Figure 12-16; Ross 1979; Mitchell and Reeves 1982; Mercier et al. 1995).

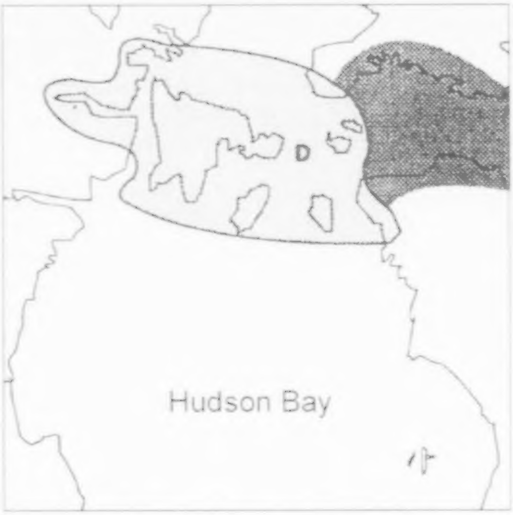

Figure 12-16. **A "hotspot" (D) of biological activity identified by participants at the 1994 Arctic Marine Workshop (adapted from Mercier et al. 1995).**

12.8 SUMMARY

Marine parks or protected areas have not been established in James Bay or Hudson Bay to protect the remarkable concentrations of beluga whales or other marine biota, although studies have been conducted to recommend areas for consideration. Protection is afforded coastal habitats and wildlife, such as the polar bear, by Wapusk National Park in northern Manitoba and Ukkusiksalik National Park in the Wager Bay area of Nunavut; Polar Bear, Kesagami Tidewater, and Winisk River provincial parks in Ontario; and Ijiraliq Territorial Park near Rankin Inlet in Nunavut. Migratory birds, particularly waterfowl and shorebirds, are protected in the James Bay area by the Boatswain Bay, Hannah Bay, Moose River and Akimiski Island migratory bird sanctuaries, along the Kivalliq coast by the McConnell River Migratory Bird Sanctuary, and on Southampton Island by the Harry Gibbons Migratory Bird Sanctuary. The Twin Islands in northern James Bay are a Territorial Game Sanctuary. A number of key terrestrial and marine habitats for migratory birds and the indigenous Hudson Bay eider are not protected.

York Factory at the mouth of the Hayes River, Prince of Wales Fort near Churchill, and Arvi'juaq near Arviat have been designated National Historic Sites. The Seal River in northern Manitoba is the only river that drains directly into Hudson or James bays that has been designated as a Canadian Heritage River.

13.0 ECOSYSTEM STRESSORS

Despite a history of resource harvesting and European habitation that dates back to the 1600's, the Hudson Bay marine ecosystem remains relatively pristine. The main human activities that have affected or may affect the natural condition of the region are related to renewable resource harvesting, marine transportation, mineral or hydrocarbon development, and sewage disposal. Activities outside the marine region related to the diversion and impoundment of freshwater, and to industrial and agricultural development, may also affect its natural condition. The pathways of key stressors as they relate to Arctic marine ecosystems are summarized schematically in Figure 13-1, and discussed in the following Chapters on harvesting, development, contaminants, and climate change.

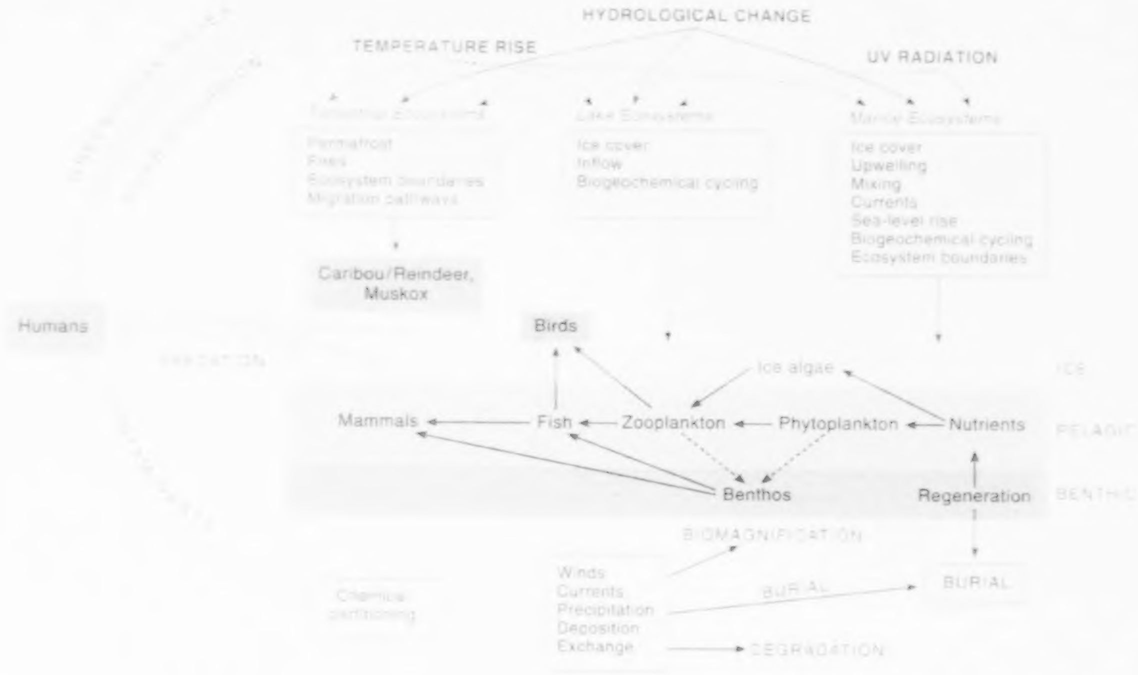

Figure 13-1. **Schematic diagram of environmental stressors (From Macdonald et al. 2003b, p. 48).**

13.0 ECOSYSTEM STRESSORS

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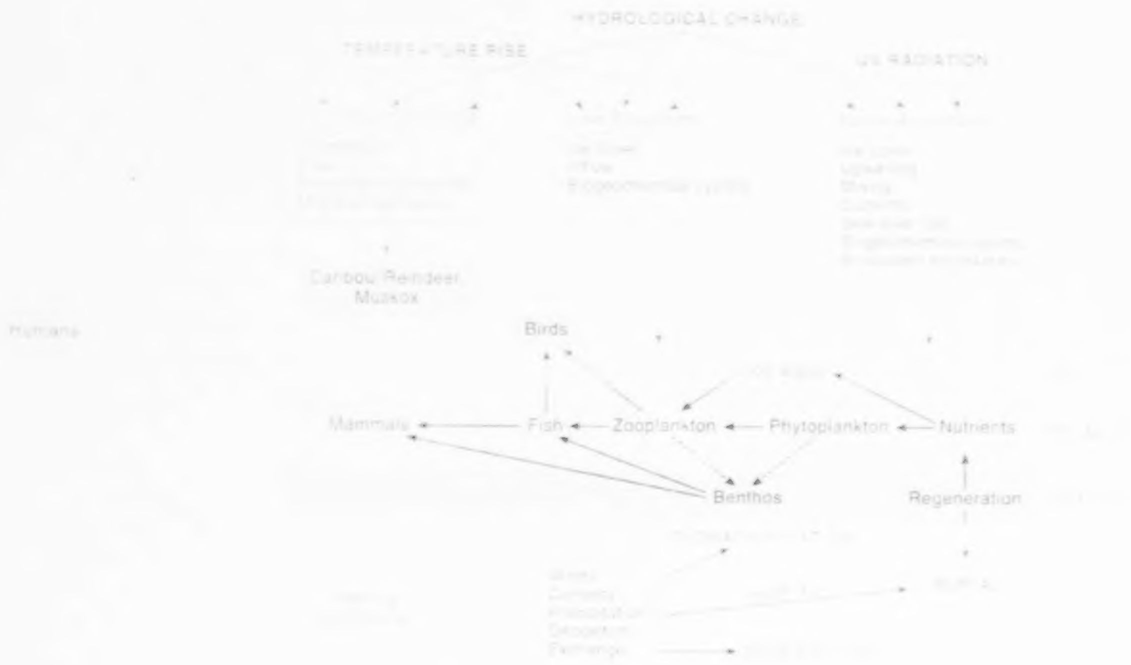

Figure 13-1. Schematic diagram of environmental stressors (From Macdonald et al. 2003b, p. 48).

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14.0 HARVESTING

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Harvesting in Hudson Bay and James Bay began millennia ago with the arrival of Indian and Inuit immigrants, and is still vitally important to their culture and well-being. Europeans began fishing and hunting in the area when Henry Hudson first visited, in 1610, and later developed commercial whaling and sealing industries that flourished. This section examines current harvest management practices and harvesting efforts in the Hudson Bay marine ecosystem by species and location, and discusses the effects of harvesting on populations, species, and habitats.

The quality of quantitative harvest data depends upon the type of harvest (subsistence, commercial, sport), the species harvested, interest on the part of the compiler, and the community. Subsistence harvests are not well documented for fish, bird, and seal species because these harvests are not limited; sport harvests are not well documented for fish and birds because they are harvested for personal use. Notable exceptions are studies in the late 1970's to establish guaranteed harvest levels under the James Bay and Northern Quebec Agreement (JBNQNHRC 1982, 1988); in the early 1980's to examine wildife harvests in the Kivalliq (Gamble 1984, 1987a+b, 1988); and of aboriginal land use in northern Ontario in the mid-1970's and in 1990 (Prevett et al. 1983; Berkes et al. 1992, 1995). The imputed value of these subsistence harvests, on a per capita basis, to Cree and Inuit living around Hudson Bay and James Bay is substantial (see Quigley and McBride 1987; Gamble 1988, and Berkes et al. 1995 for more information). A new study of subsistence harvesting in Nunavut was not available at writing but should provide updated information on subsistence harvests in the Kivalliq (western Hudson Bay) region (M. Wheatley, NWMB, Iqaluit, pers. comm. 2004).

Better records are available for the larger marine mammal species that are harvested for subsistence, and occasionally for sport. Concern over the ability of beluga, narwhal, bowhead, polar bear, and walrus populations to support current rates of removal has resulted in regulation, and harvest monitoring. Monitoring measures range from reports on licenced harvests or quotas to informal observations of how many animals are landed. The communities are required to report their harvest for whales and walrus, and sport hunt for walrus is tightly controlled (P. Hall, DFO Winnipeg, pers. comm.). Because these species are large, their harvest is an event and they are more likely to be seen and recorded by resource managers. Licensing requirements for the sale and/or export of products from these animals also create a secondary record of the harvest.

Records from the commercial sale of marine invertebrates, anadromous fishes, and seal pelts can provide good data on the number of animals harvested each year for export. These records are often available from the local fish plant, retail outlets, or hotels. They tend to underestimate local sales, particularly direct sales by the harvester to the consumer.

14.1 HARVEST MANAGEMENT

Harvest management within the region is complicated by the migratory habits of many of the harvested species, which make them vulnerable to harvest in other jurisdictions. Coastal Arctic charr quotas in western Hudson Bay that specify the fishing area can, for example, target fish from several stocks as they move along the coast. While the migratory marine mammals of the Hudson Bay marine ecosystem are vulnerable to harvest in other areas, such as Hudson Strait and Davis Strait, few range outside the coastal waters of Nunavut and Nunavik. This limits their vulnerability in jurisdictions other than those that also border on Hudson Bay, and thereby the difficulties in co-operatively managing hunts to ensure that they are sustainable. Harp and hooded seals, which winter in the North Atlantic, are perhaps the most notable exceptions.

In contrast, waterfowl and seabirds are long distance migrants that may be vulnerable to harvest from the High Arctic to the southern United States. Every territory, province, state, and country on the annual migration route of these birds has a vested interest in ensuring that the population can sustain the levels of harvest, but their citizens also want their fair share of that harvest. This makes management of these transboundary migrants very complex. The problem is usually one of how to avoid overharvesting shared resources. However, lesser snow goose populations, which have increased dramatically in response to changing agricultural practices in the southern United States and to effective conservation programs, present the opposite and unusual problem of overabundance (Abraham et al. 1996; Johnson 1996a; Abraham and Jefferies 1997; Rockwell et al. 1997). This has led to cooperative hunt management among the various jurisdictions to reduce the populations to a level that can be sustained by the environment and thereby avoid a catastrophic decline in the populations (Johnson 1996b, 1997; Batt 1997). These birds make up a substantial portion of the diet of the Cree living around James Bay and southern Hudson Bay, and a smaller but still important contribution to the diet of Inuit living around Hudson Bay. So, the effects of any large decline in their numbers would have strong adverse impacts on subsistence harvesters and could increase harvesting pressure on other species.

Harvest management in Nunavut, which includes the islands in Hudson Bay and James Bay, changed with signing of the Nunavut Land Claim Agreement (NLCA) in 1992 (TFN and DIAND 1992). The NLCA established the Nunavut Wildife Management Board (NWMB) an institution of public government, which consists of four Inuit appointees and four government apointees plus a chairperson. This co-management board is responsible for wildlife management decisions for Nunavut, including setting quotas and non-quota limitations (e.g., fishing and hunting seasons, methods of harvest), approving management plans, and approving the designation of endangered species. The NWMB also has two alternate members from Makivik Corporation who represent the Inuit of Nunavik when the Board discusses issues relating to the Areas of Equal Use and Occupancy that are shared by Nunavut and Nunavik. Harvest management decisions were formerly the responsibility of various government departments, including GNWT Department of Renewable Resources (terrestrial mammals including polar bear), DFO (fish and marine mammals), and Environment Canada (EC; migratory birds and endangered species). Ultimate approval of the NWMB decisions rests with Nunavut's Minister of Sustainable Development and the Federal Government's Minister of Fisheries and Oceans and Minister of the Environment. However, Inuit harvesting may only be limited if there is a conservation concern, or a concern about public health or public safety. The NWMB relies on the government departments for scientific research and advice, and for regulatory support and enforcement. NWMB decisions are implemented under legislation enacted by the approporiate government departments, such as the Nunavut Wildlife Act or the Fisheries Act. Harvest restrictions or quotas that were in force on the date immediately prior to ratification of the NLCA (Sec. 5.6.4), remain in effect until removed or otherwise modified by the Board.

Priority is given to Inuit and Cree subsistence harvesters when resources in Hudson Bay and James Bay are allocated (JBNQNHRC 1982; Yaremchuk and Wong 1989a+b; TFN and DIAND 1992). Where animal populations harvested by Nunavut and/or Nunavik are considered at risk of overharvesting, the total allowable harvest they can sustain and the basic needs level for native subsistence is determined. Under the Nunavut Land Claim Agreement (NLCA)(TFN and DIAND 1992), if the basic needs level falls below the total allowable harvest for a given stock, the surplus in the allowable harvest may be allocated, in order of preference, to non-native residents or their dependents for personal consumption, to sustain existing sport and commercial ventures, to provide for economic ventures sponsored by native organizations, and to other users (see NLCA Section 5.6.32-5.6.40 for details).

People wishing to remove animal parts from Nunavut require either a Wildlife Export Permit from the Department of Sustainable Development ([illegible]) or a Marine Mammal Transportation License from Fisheries and Oceans Canada (DFO). The Wildlife Export requirement applies to birds and terrestrial mammals, including polar bears, and includes legally killed game, gifts of meat from a hunter, legally purchased meat, ducks or geese, and any other animal parts. Unless they were killed under the authority of a licence, birds of prey, polar bears, grizzly bears, muskoxen, and their parts also require Certification. Wildife parts used in manufactured products, such as parkas or antler carvings, do not require a Wildlife Export Permit. A separate licence is required to export live wildlife.

A Marine Mammal Transportation Licence is required under the *Fisheries Act* to move marine mammal (whale, seal, walrus) parts across provincial and territorial boundaries. However, this requirement does not apply to Indians or Inuks who harvest animals in one jurisdiction, and are returning to their home in another jurisdiction. Both raw products, such as meat and pelts, and manufactured products, such as ivory carvings, require this licence. Permits are not required to export fish from Nunavut, but proof that they were obtained legally may be required.

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) controls the international movement of species that are considered to be at risk from commercial trade (see [illegible], [illegible] for more information). A Canadian CITES Export Permit is required before shipping the parts, products and derivatives of many species found in the Hudson Bay marine ecosystem, such as beluga, narwhal, killer whale, walrus, polar bears, and some birds of prey. International commercial trade is forbidden for species listed on CITES Appendix I, such as the large whales (e.g., bowhead, minke, and sperm), Eskimo curlew, gyrfalcon, whooping crane, peregrine falcon, and bald eagle.

International trade in species that are considered to be endangered or threatened, or potentially so, is controlled under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Some species found in the Hudson Bay marine ecosystem that generally cannot be exported from Canada include: bowhead whale, Eskimo curlew, gyrfalcon, humpback whale, whooping crane, peregrine falcon, and bald eagle. Species that may be exported from Canada with a CITES permit, provided they were obtained legally, include: beluga, narwhal, killer whale, polar bears, birds of prey (except the species noted above), and Atlantic walrus. CITES permits are required for all parts of these species, including manufactured products.

Harvest management along the Nunavik coast and its estuaries changed with signing of the James Bay and Northern Quebec Agreement in 1976 (Quebec 1976). Under this agreement, Inuit and Cree beneficiaries of the agreement are guaranteed certain levels of harvest. These levels were established on the basis of harvest levels observed during the period 1975-6 to 1978-9 for the Cree (JBNQNHRC 1982) and 1976 to 1980 for the Inuit (JBNQNHRC 1988). They are to be maintained unless their continuation is contrary to the principles of conservation. Decisions related to marine fish and mammals are still the responsibility of DFO, but the department makes them in cooperation with Anguvigak Wildlife Management Inc. and the Makivik Corporation. The interests of Inuit hunters, fishermen and trappers in Nunavik are formally represented by Anguvigak: The Nunavik Hunting, Fishing and Trapping Association (Nunavimmi Umajulirijiit Katutjiqatigiininga) (see [illegible]). Anguvigak consists of locally elected representatives and interacts with the responsible government departments on all wildlife-related activites in Nunavik, including resource management, research, and harvesting. The Makivik Offshore Claim, which is under negotiation, will cover the coastal areas around western and northern Quebec. If approved, it may alter the management of fish and wildlife offshore the Nunavik coast in a fashion similar to the Nunavut agreement.

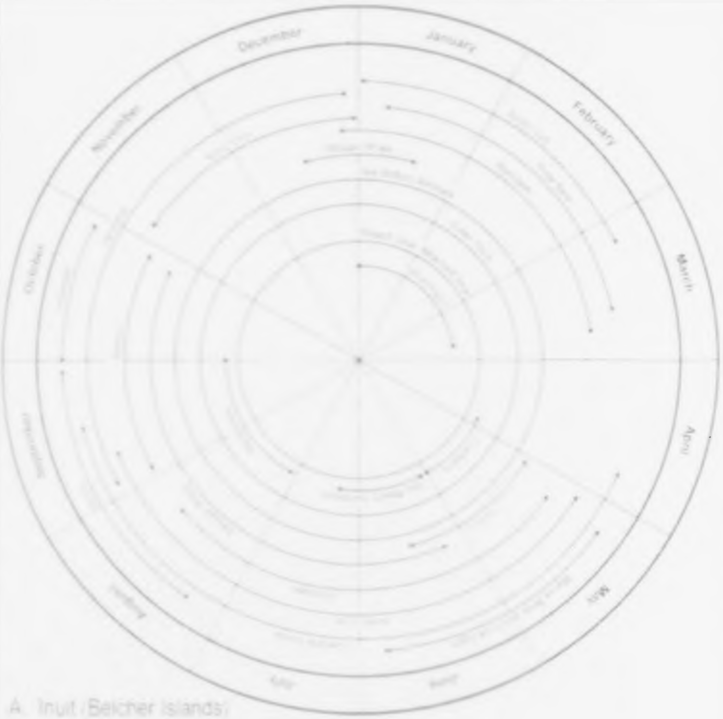
The responsible department of the Federal or Provincial Government manages fish and wildlife hunts along the Ontario and Manitoba coasts.

Quotas and other harvest management provisions for various species are discussed further below.

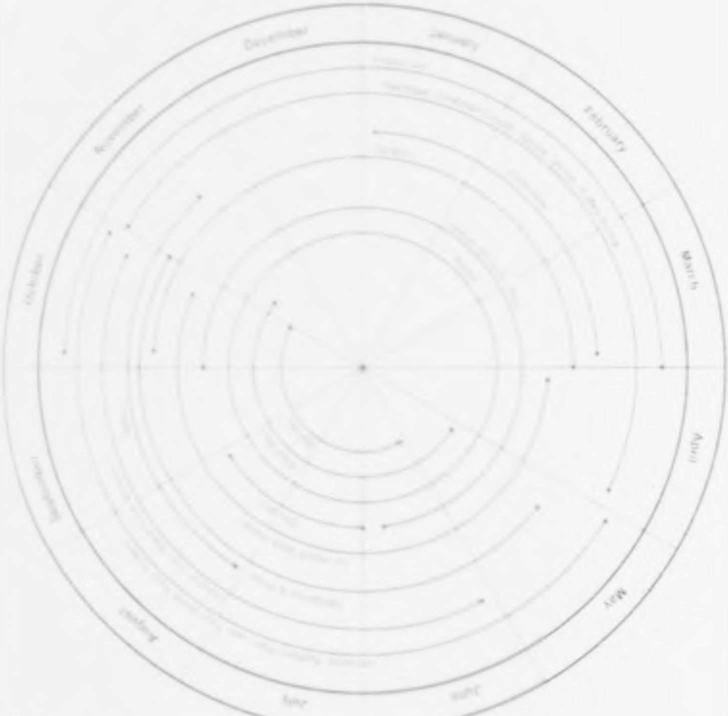
14.2 MARINE PLANTS

Inuit in the Belcher Islands harvest seaweed (*Rhodymenia* spp.) and kelp (*Laminaria* spp.) for food in October (Wein et al. 1996; McDonald et al. 1997), but otherwise the subsistence harvests of marine plants from Hudson Bay are poorly documented (Figure 14-1). This practice may be widespread but irregular in Arctic Canada, as Inuit from Qikiktarjuaq also harvest kelp for food (Stewart 1994).

Kivalliq Land and Sea Resources Ltd. has been working to develop a viable commercial harvest of kelp in the vicinity of Whale Cove since the mid-1990s (Aurora Research Institute 1996; Koppel 1997; DFO 1997, 1999b). Options under consideration have included processing kelp for health food, and composting it to produce methane



A. Inuit (Belcher Islands)



B. Cree (western James Bay)

Figure 14-1. **Seasonal foods of: A) Belcher Islands Inuit and B) western James Bay Cree (from McDonald et al. 1997).**

gas and fertilizer. In 2000 the company harvested 35 MT of kelp from the vicinity of Whale Cove (Minutes of NWMB Regular Meeting #27: 8.K). The NWMB approved a quota increase to 320 MT of dulse, kelp, and rockweed for the 2001 season (NWMB Resolution 2000-224). It was contingent on a number of conditions; in particular that a monitoring plan be in place before harvesting commences and that there be community support. No license was issued for this fishery in 2003 (G. Reid, DFO Iqaluit, pers. comm. 2004). In September 2001, the NWMB approved requests by the Arviat and Chesterfield Inlet HTO's for small harvest quotas on rockweed (1MT) and on dulse and kelp (4 MT) (NWMB Resolution 2001-076). Similar quotas requested by the Ingnirq Development Corporation for the Whale Cove area were to be harvested under the 320 MT quota approved earlier.

14.3 INVERTEBRATES

Many invertebrate species are vital links in the food chain between the primary producers and larger fish and marine mammals, but few are harvested from the Hudson Bay marine ecosystem for human consumption. No commercially attractive invertebrate species has been located in sufficient abundance to justify the establishment of an offshore commercial fishery. The commercially attractive species are also small and slow growing relative to their southern counterparts (Squires 1967; Lambert and Prefontaine 1995; Doidge et al. 1995), and fishing is relatively expensive due to the short open water season and high costs of remote operation.

Inuit from the Belcher Islands harvest green sea urchin (*Strongylocentrotus droebachiensis*), brown sea cucumber (*Cucumaria japonica*), six-rayed starfish (*Leptasterias polaris*), and blue mussel

(*Mytilus edulis*) for food yearround (Figure 14-1) and there has been interest in commercially harvesting these species (Jamieson 1986; Topolniski et al. 1987; Crawford 1989; Giroux 1989; Wein et al. 1996; McDonald et al. 1997). These urchins and mussels are significantly smaller than those harvested by competing southern fisheries (Kramer 1980; Lubinsky 1980). Preliminary studies of the commercial potential indicate that these invertebrates are not sufficiently abundant to support more than a small fishery to supply the local market in Sanikiluaq and the coastal villages of eastern Hudson Bay (Jamieson 1986; Giroux 1989). There is also recent interest in the harvesting of scallops by divers (G. Reid, DFO Iqaluit, pers. comm. 2004).

In 1989, Makavik Corporation surveyed northern Hudson Bay for shrimp using the offshore trawler "Kinguk"—few were caught (M. Allard, Makivik Corp., Lachine, QC pers. comm.). In August and September 1990, an exploratory cruise for Iceland scallops (Chlamys islandica) sampled a number of small scallop beds near the Quebec coast from Ivujivik to south of Inukjuak (Morin 1991; Dalcourt 1992; Lambert and Prefontaine 1995). These beds were too small to justify commercial development. Field programs were carried out at Akulivik in 1994-96 to assess the harvest potential of blue mussels (Doidge 1995; Doidge and Prefontaine 1997).

Small commercial harvest quotas have been approved for exploratory clam, scallop, amphipod, shrimp, and blue mussel fisheries in Kivalliq since the early 1990's (Stewart 1994; DFO 1995, 1996, 1997, 1999b; NWMB Resolution 2001-076). Most recent interest has been centred at Whale Cove, but in the past there was interest on the part of Arctic Cooperatives Ltd. in harvesting blue mussels near Arviat for sale in Winnipeg (J. McMillan, Arctic Coop. Ltd., Winnipeg, pers. comm. 1990). Since April 2003, DFO has only issued Scientific Licences for shellfish in Nunavut, scallops excepted, since there is no Canadian Shellfish Safety Program inspection available to ensure the safety of shellfish harvested for commercial sale under exploratory or commercial licences (G. Reid, DFO Iqaluit, pers. comm. 2004). In 1994, 3000 kg of amphipods were harvested in the Whale Cove area (DFO 1996). In 2000, the NWMB approved the request by Canadian Sea Urchin Harvesting Limited for a quota of 50,000 kg of green sea urchins (or 5,000 kg of sea urchin eggs) to be taken in the Whale Cove area (NWMB Resolution 2000-177). This quota was approved too late for fishing to be undertaken in 2000. It was approved again for 2001 (NWMB Resolution 2000-225) and this approval was extended for a further 5 years (NWMB Resolution 2001-040), subject to a number of conditions and annual approval.

To our knowledge, blue mussels are the only marine invertebrates harvested on a regular basis for subsistence by residents of western Hudson Bay. They are readily available at extreme low tides at many locations along the coasts and make a tasty meal. In the east, Inuit from Inukjuak, Umiujaq and Kuujjuarapik harvest blue mussels at many sites in the Hopewell, Nastapoka, Manitounuk, and Long islands areas and along the southeast coast of Hudson Bay for domestic consumption (Doidge 1992a,b; see also Saladin d'Anglure 1984). Most mussels are harvested from the intertidal zone, but residents of Akulivik also harvest them from the subtidal zone, using drags in summer and long-handled scoops in winter (Mesher and Doidge 1995; Doidge and Prefontaine 1997).

The impacts of marine plant and invertebrate harvests on the target species, their habitats, and other species that eat them or use the affected habitat have not been studied. The ability of plant and invertebrates to sustain harvests, and the rate of recovery of bottom habitats damaged by dragging or other methods of harvest, is unknown. The selective harvest of invertebrates in the Belcher Islands by divers is an exception, as it causes little damage to other species or habitats.

14.4 FISH

14.4.1 Subsistence Fishing

Inuit and Cree food fisheries catch most of the fish harvested from James Bay and southeast Hudson Bay, and a substantial percentage of those harvested elsewhere in Hudson Bay. There is no tradition of offshore marine fishing but there are well-developed estuarine and coastal fisheries during the open water season. These subsistence fisheries have considerable economic value (Quigley and McBride 1987; Berkes et al. 1992; Fast and Berkes 1994; Wein et al. 1996). Fish are harvested for the food they provide, and as a traditional social and cultural activity. The cultural influence of the fishery even extends to children's games. Edwards (1961) described a game played by Inuit children in Richmond Gulf (Lac Guillaume Delisle) wherein a live sea tadpole (*Careproctus reinhardti*) "*is placed on the bare arm to which it fastens with its sucker. The child then runs around with it, and the other children attempt to snatch it away.*" Unlike commercial and sport fisheries, subsistence fisheries by registered native peoples in Canada are not subject to government regulation.

Anadromous Arctic charr are the fishes most sought after for subsistence by Inuit in Nunavut (Brack 1962; Brack and McIntosh 1963; Schwartz 1976; Welland 1976; Gamble 1984, 1987a+b, 1988) and Nunavik (Berkes and Freeman 1986; JBNQNHRC 1988)(Table 14-1). These fish are available at predictable times and locations each year. They are easy to catch using gillnets, grow relatively quickly and to a good size, and are relatively free of parasites that infect people. Subsistence fisheries for anadromous Arctic charr begin in coastal regions in late May and continue until late September (Figure 14-1) --earlier than the commercial harvests, which avoid recent downstream migrants that are often in poor condition after winter starvation. Anadromous charr are also taken at inland lakes where they winter. Most harvesting takes place near the communities either along the coasts or at river mouths. In Kivalliq, anadromous Arctic charr are harvested along the coast from the Thlewiaza River north to Daly Bay and into Chesterfield Inlet, in the Repulse Bay area, and at the Thomsen River in northwest Southampton Island. Many of the same sites are fished commercially, sometimes at the same time and often with the same gear, but the subsistence fishery is not restricted in terms of the fishing area, season, or harvest (Yaremchuk and Wong 1989b). There are small harvests of Arctic charr at Churchill, where the species is less common but a welcome treat (McRae and Remnant 1997). There are substantial subsistence harvests of anadromous Arctic charr along the Quebec coast from Kuujjuarapik northward, and in the Belcher Islands. The charr are eaten fresh or preserved for future use by drying, freezing or, rarely, smoking. Species caught incidentally, such as cod or sculpin are also eaten on occasion. Dogs are sometimes fed fish, usually freshwater coregonids but sometimes Arctic charr. Anadromous whitefish and brook trout dominate the catches by residents of Kuujjuarapik and Chisasibi (Schwartz 1976; Berkes and Freeman 1986; JBNQNHRC 1988) (Table 14-1).

Greenland cod (*Gadus ogac*), Arctic cod (*Boreogadus saida*), and sculpins (*Myoxocephalus* spp.) are the only marine species commonly harvested by Inuit. Richmond Gulf Inuit understand the winter movements of Greenland cod, as was demonstrated to Edwards (1961) by three women who caught about 300 lbs (133 kg) of cod through the ice one morning! Capelins are also harvested when they spawn at the shoreline in the Belchers (Hunter 1968; Fleming and Newton 2003). Subsistence harvests of cod and sculpin are much greater in eastern than in western Hudson Bay. Quebec Inuit also harvest Atlantic salmon (ouananiche) either from fresh water or brackish coastal waters.

Inuit catch most fish in gill nets but some by angling, jigging, spearing with leisters, or trapping in stone weirs (Berkes and Freeman 1986). Inuit from Kuujjuarapik traditionally used these weirs to harvest Arctic charr at rivers entering Richmond Gulf (Berkes 1979), and weirs may still be used on occasion at some rivers in Kivalliq.

The Cree coastal subsistence fisheries depend largely on four anadromous species: cisco, whitefish, longnose sucker, and brook trout (Berkes 1979; JBNQNHRC 1982; OMNR 1985; Thompson and Hutchison 1989; Berkes et al. 1992) (Table 14-1). Most fish are caught using gillnets; some fish are caught using jigs, rod and reel, set lines, beach seine type hand-held sweep nets, or stone fish weirs. The stone weirs, which may represent Inuit influence, have been used on the Rupert River to trap whitefish, and south of Chisasibi. Fishing effort is dispersed over a large area, with family groups each having their own traditional fishing areas (Berkes 1979). Most stocks appear to be lightly utilized but the subsistence harvesters overfish some stocks in the vicinity of the communities:

> *"The major management problem is how to harvest the sparse production of a large area, where the stocks consist of old fish, available in large and conveniently fishable units, but where the rate of renewability of the resource is very low."--Berkes and Freeman (1986).*

Table 14-1. Estimated mean annual subsistence harvests of fishes by communities around Hudson and James Bays. Sources listed below.

Community	Period	Source	Hunters	Human Population[1]	Marine		Anadromous		
					cod	sculpin	Arctic charr	Atlantic salmon	brook trout[2]
QUEBEC									
Waskaganish	1975-6 to 1978-9	1	Cree	999					800
Eastmain	1975-6 to 1978-9	1	Cree	319					2667
Wemindji	1975-6 to 1978-9	1	Cree	665			26		3357
Chisasibi	1975-6 to 1978-9	1	Cree	1603			512		21615
	1976-80	2	Inuit	42	104	82	15		194
Kuujjuarapik	1975-6 to 1978-9	1	Cree	373			103		3921
	1976-80	2	Inuit	558	2481	4444	866	61	4294
Umiujaq	no data		Inuit	-[4]	-	-	-	-	-
Inukjuak	1976-80	2	Inuit	530	3152	456	14251	160	1289
Puvirnituq	no data		Inuit	-	-	-	-	-	-
Akulivik	1976-80	2	Inuit	140	293	220	13597	29	5
Ivujivik	no data		Inuit	-	-	-	-	-	-
ONTARIO									
Moose Factory/ Moosonee	1990	3	Cree	3000					3092
Fort Albany	1990	3	Cree	625					
Kashechewan	1990	3	Cree	1000					3
Attawapiskat	1990	3	Cree	1214					11
Peawanuck	1990	3	Cree	227					4278
Fort Severn	1990	3	Cree	332					4115
MANITOBA									
Churchill[3]	May 1995-Apr 1996	5	not stated				55		
NUNAVUT									
Arviat	1983-85	4	Inuit	1022	53	2	2643		
Whale cove	1982, 1984-5	4	Inuit	188			3327		
Rankin Inlet	1982-85	4	Inuit	1109	12	13	7361		
Chesterfield Inlet	1983-85	4	Inuit	249			237		
Coral Harbour	1984-85	4	Inuit	429	170	5	4503		
Repulse Bay	1982-85	4	Inuit	352			1935		
Sanikiluaq	1980-84	5	Inuit	383	817	1133	9398	-	-
TOTALS					7082	6355	58829	250	49641

Sources: 1 = JBNQNHRC 1982, 2 = JBNQNHRC 1988, 3 = Berkes et al. 1992, 4 = Gamble 1988, McRae and Remnant 1997, 5 = Pattimore pers. comm.

1 Populations are for the Aboriginal communities except in Nunavut, where the community populations ca. 1985 are listed from the 1985 Explorers Guide. The Quebec Cree populations are 5-year means 1974-5 to 1978-79 (JBNHRC 1988); the Quebec Inuit populations are from 1976 (JBNQNHRC 1982); Ontario Cree populations are from 1990, except Attawapiskat (1989) (Berkes et al. 1995).

Table 14-1. continued

Mixed andromous and freshwater						Freshwater	
burbot	lake trout	northern pike	suckers	sturgeon	whitefish[3]	Arctic charr	walleye
89	82	685	3350	229	13928		1939
201	124	566	487	94	11293		385
1581	290	1388	2649	155	23937		985
3355	5310	4942	15009	615	48807		1936
	99				1091		
273	3807	1028	4270		11781		
	818				4064		
-	-	-	-	-	-	-	-
	10756				8063		
-	-	-	-	-	-	-	-
	1300				2146		
-	-	-	-	-	-	-	-
290		6049	2344	3174	20583		8933
0		304	53	68	727		162
829		2937	1454	300	5307		3283
3377		11956	5294	1223	21670		9694
44		1801	1353	3	5237		142
666		796	162		4032		95
		438	163	1	672		1
	733	29			265		
	301	2			76		
	354				8		
	212						
	303						
-	-	-	-	-	-	1576	-
10705	24488	32921	36588	5862	183687	1576	27555

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[2] brook trout = speckled trout. [3] whitefish includes whitefish and ciscos, mostly lake whitefish and lake cisco.

[4] Dashes indicate no data; blank cells indicate no harvest reported.

[5] Churchill data are reported rather than estimated harvests from 67 of 182 people identified as domestic harvesters; 12 Arctic grayling were also harvested.

Much of the catch is consumed immediately at the fishing camps; the rest may be sun-dried, smoked, or frozen whole. Year-to-year variations in the availability of other game and in environmental variables such as the water level, temperature, wind speed and date of freeze-up make it very difficult to estimate the total catch of the Cree subsistence fishery (Berkes 1979). Cree along the Ontario coast of James Bay rarely harvest any purely marine fish (Berkes et al. 1992).

14.4.2 Commercial Fishing

Commercially attractive marine fishes have not been found in sufficient quantity to support a viable marine fishery in Hudson Bay (Hachey 1931; Huntsman 1931; Hunter 1968; Dunbar 1970; Morin 1991) or James Bay (Brooke 1992; Dalcourt 1992). Huntsman (1931) quoted Pennant who wrote in 1784 concerning Hudson Bay:

> *"the Company have attempted to establish a fishery: and for that purpose procured experienced people from the Spitzbergen ships, and made considerable trials between lat. 61 and 69; but after expending twenty thousand pounds, and taking only three fish, were, in 1771, obliged to desist."*

In 1930, based on the results of the Loubyrne fishery, Hachey (1931) wrote:

> *"The "Loubyrne" was engaged in actual fishing operations in Hudson Bay for 22 days. During that time 200 miles of bottom representative of the whole region were efficiently dragged for commercial fish. Added to this, other methods of fishing were indulged in. Not a single commercial fish was taken. Hence it is quite easy to arrive at a definite conclusion that a deep-water fishery of commercial importance does not exist in Hudson Bay."*

This oft cited conclusion has effectively limited offshore fisheries research in Hudson Bay since 1932 and although it may be valid and apply equally to James Bay, it is based on very limited fishing effort. During the 22 days, hand lines were used for a total of 7.25 h, drift nets for 12 h, longlines for 2.92 h, and an otter trawl for 57.83 h. To make such a sweeping conclusion about the offshore fishery potential of all Hudson Bay may not have been reasonable (HBC Archives GR1600-94555 Letter from J.M. Davidson February 5, 1932). The limited fishing effort was not sufficient to test for the seasonal presence of large schools of capelin, which we now know to occur in Hudson Bay (Fleming and Newton 2003), or for Atlantic cod, which occur in Hudson Strait.

Lacking a proven offshore resource, and limited by the climate and technology, fisheries investigations in Hudson Bay and James Bay in the 20th century concentrated on exploring the commercial fishing potential of the coastal estuaries (Lower 1915; Melvill 1915; Halkett 1919; Vladykov 1933). Unfortunately, the fish populations proved to be relatively small and slow-growing (Hunter 1968; Roy 1989). They consisted mainly of old individuals, and were unable to support both commercial export fisheries and the vitally important subsistence harvest. Fisheries for anadromous Arctic charr along the Kivalliq coast offered perhaps the only exception.

Commercial fishing for anadromous Arctic charr along the Kivalliq coast began in 1931 when Mr. Ingebrigtsen of Churchill, Manitoba sailed 250 km up the coast and harvested about 2000 kg of charr, marketing them as "lightly salted sea trout" (Dalrymple 1932). Despite the success of this small fishery there was little interest in commercial fishing until 1962 when the Rankin Inlet nickel mine closed. To help shore up the area economy the Department of Northern Affairs and Natural Resources (DNANR), and later the GNWT, helped to develop a commercial fishery for fish and marine mammals in the area (Carder and Peet 1983).

In 1964, following a brief survey of fish resources along the Kivalliq coast (Brack and McIntosh 1963), the DNANR established a pilot cannery plant at Daly Bay, north of Chesterfield Inlet (Lantz 1965; Lantz and Iredale 1972). The cannery employed local Inuit to harvest and process Arctic charr, seals, whales, and walrus from the area. In 1966, after the fish resources of Daly Bay had proven to be insufficient and because the water supply, power, and housing facilities were limited, the cannery was dismantled and re-established at Rankin Inlet as the Issatik Food Plant (Iredale 1984).

Exploratory fisheries were undertaken in the Rankin Inlet area to find exploitable fish stocks to support the cannery and Arctic charr were marketed in the south as a gourmet product (Carder and Peet 1983). In 1970, with the discovery of high levels of mercury in the marine mammals and decreasing local demand for the products, the cannery stopped processing marine mammals. The fish canning operation continued until 1976, when high transportation costs to southern markets forced it to close (Thompson 1976; Carder and Peet 1983). The facility continued to process fresh and frozen Arctic charr for commercial sale in the community and to the Freshwater Fish Marketing Corporation (FFMC) in Winnipeg into the early 1990s when, as the Keewatin Meat and Fish Co. it also began processing caribou for sale within the Northwest Territories. The plant burnt down in 1997 (McGowan 1998) and was subsequently rebuilt. Today, operating as Kivalliq Arctic Meats it is a Federally Inspected meat processing plant with European Union Certification that processes fresh and frozen Arctic charr and caribou for sale directly to domestic and international markets (http://www.nnsl.com/ops/countryfood.html; K. Pelley, DFO Rankin Inlet, pers. comm. 2003). It serves as the central processing facility for caribou and fish harvested in the Kivalliq Region. In 2003, the plant employed 17 people year-round and handled 118,000 kg of caribou. Because the volume of fish taken in the area is lower, the plant cannot afford to suspend caribou production to process fresh fish in the summer, so the initial processing of fish from the Arviat-Whale Cover-Rankin Inlet area (cleaning and freezing) is now done at Whale Cove (B. Zawadski, Nunavut Dev. Corp., Rankin Inlet, pers. comm. 2004). Frozen charr purchased from Whale Cove and Chesterfield inlet, are cut into fillets and some are hot-smoked after caribou processing has been completed. In recent years the plant has purchased about 7,500 kg (dressed weight; dr. wt) of charr annually from Whale Cove and about 4,500 kg (dr. wt) from Chesterfield Inlet.

In the 1980's and 1990's there was also a small registered fish plant at Chesterfield Inlet where charr were cleaned, packed, and shipped fresh or frozen to the FFMC. There were small, unregistered packing stations at Arviat and Whale Cove that also shipped fresh charr to the FFMC, and freezer/packer vessels at Whale Cove and Coral Harbour (Stewart et al. 1993). Today, Arctic charr harvested by Whale Cove and Chesterfield Inlet are frozen locally and then shipped to Rankin Inlet for processing; some fish are shipped fresh (B. Zawadski, Nunavut Dev. Corp., Rankin Inlet, pers. comm. 2004). In 2003, the plant processed 7,766 kg (dr. wt) of Arctic charr purchased from 13 Whale Cove and 10 Arviat residents.

Historically, none of these fish processing operations has received enough fish to consistently meet operating expenses. Their operating losses were substantial and they did not produce a return on the initial capital investment (Ference and Associates Ltd. 1987; NWT Economic Strategy Panel 2000). Fishermen in the Kivalliq communities, with a few exceptions, participate in the commercial fishery not to earn a livelihood, but to supplement their incomes or subsidize subsistence harvests (Yonge 1988, 1989).

The main commercial fishery is conducted during August and early September when anadromous Arctic charr are netted at or near river mouths along the coast (Bond 1974; Carder 1983, 1988, 1993, 1995; Carder and Peet 1983; Carder and Low 1985; Carder and Stewart 1989; Yaremchuk et al. 1989; McGowan 1998). Long standing commercial harvest quotas at these locations are opened annually, as requested by the Hunters and Trappers Orgainzations, unless there is strong evidence of overharvesting. Nets are generally 45 or 90 m in length with 139 mm mesh, and 20 to 30 meshes deep. They are usually stretched out from shore on the surface where the water is 4 to 5 m deep and checked twice daily. Metal conduit fish weirs have also been used to harvest migrating anadromous charr at some rivers in the fall (McGowan 1987; Hollett 1993; DFO 1999b). The fish are dressed on site, packed in ice, and transported by boat to the fish plants for washing, fast freezing, and packing. They are then shipped to market on scheduled airlines. In 1988-9 Chesterfield Inlet, Rankin Inlet, Whale Cove, and Arviat together harvested 37,085 kg of dressed Arctic charr during the open water season (Carder and Stewart 1989). Most of these fish were sold to the FFMC, either fresh or frozen. The remainder were sold locally or in nearby communities, or culled. In 1996-7 the Kivalliq communities harvested 22,933 kg (rnd wt) of Arctic charr (DFO 1999b). There is a small commercial fishery for Arctic charr in the Belcher Islands (Read 2000) and a small, sporadic commercial fishery for Arctic charr at Churchill (Carder and Stewart 1989; DFO 1997).

Transportation poses a problem for the Kivalliq fisheries both in terms of logistics and cost (Stewart et al. 1993). Boat transportation from the rivers to the fish plants, and air transportation from the fish plants to southern markets are both hampered by inclement weather. Fishermen are often stranded at a site for days if there is a storm on Hudson Bay. Likewise, shipments of fresh fish are sometimes stranded in the communities and must be unpacked, frozen, and repacked, and shipments of frozen fish can be stranded in Rankin Inlet or Churchill -- increasing spoilage.

While commercial and sport fisheries are regulated, overharvesting can occur in areas that also support large subsistence fisheries. One such area is the Diana River near Rankin Inlet (McGowan 1987), where commercial fishing was stopped and sport fishing reduced to enable stocks to recover. In the early 1990's, subsistence fishermen also agreed to stop fishing the spring downstream run and to use only 139 mm (5.5") mesh gillnets throughout the season in the area of the river mouth to speed the rate of recovery (G. Weber, DFO, Rankin Inlet, pers. comm.). In the early 1990s, the Kivalliq communities expressed concern that charr were becoming less abundant and smaller in some areas (McGowan 1998). A study of the growth and movements of the fishes and of the catch per unit effort by the fisheries found that the average age of charr landed from various quotas by the communities declined from the 1980s to mid-1990s. This can occur in response to fishing pressure, so further monitoring was recommended. The movement studies demonstrated the extensive movements of these fish and that mixed stocks are being harvested under the coastal quotas.

Commercial harvesting of coastal marine and estuarine fish is conducted on a small local scale at many communities along the Quebec coast, and fish are often marketed through local cooperatives (Berkes 1979; M. Breton, DFO, Quebec, pers. comm). Richmond Gulf was the site of a commercial fishing venture from 1962 to 1964 for anadromous brook trout, whitefish, cisco, and Arctic charr (Hunter 1968; Power and Lejeune 1976; Gillis 1988). Declining catches and unfavourable economics led to the closure of this fishery. In 1989, the 50 m factory trawler "Kinguk" surveyed offshore waters of northern Hudson Bay for shrimp and Greenland halibut (turbot), with very poor catches (M. Allard and G. Fisk, Makivik Corp., Lachine, pers. comm.). A marine test fishery was conducted in the vicinity of Wemindji in 1987-88 and 1988-9 (Breton 1990; Brooke 1992; Dalcourt 1992). Its purpose was to assess the feasibility of harvesting marine fishes to feed fox and mink at local fur farms, and capelin for export to the Japanese market (F. Berkes, Univ. of Manitoba, Winnipeg, pers. comm.). Sculpins, Greenland cod, and anadromous whitefish were harvested in the greatest numbers, but not in sufficient numbers to justify commercial development (Dalcourt 1992).

There is also a small commercial fishery for anadromous Arctic charr at Puvirnituq (C. Choquette, Kativik Regional Government, Kuujjuaq, Quebec, pers. comm.). Fish are purchased by Fumoir à poisson Pitsituuq Inc., which in the early 1990s used about 8,500 kg (round weight; rnd wt) of charr annually to produce about 4,250 kg of smoked product. The smokery is a one-man operation that employs two helpers during peak periods. Plant production is limited by the local supply of charr and most of the product is sold locally. The sustainable harvest potential of the region was not assessed prior to plant construction and remains unknown. Small quantities of charr (700 kg) are occasionally imported from Ungava Bay.

14.4.3 Sport Fishing

The Provincial and Territorial governments share responsibilities with the Government of Canada for managing recreational fisheries along their coasts (Table 14-2).

There is no marine trophy fishery in Hudson Bay or James Bay. Tourists seeing trophy Arctic charr generally fish along the central Arctic coast or on the Arctic Islands. Sport anglers do catch anadromous Arctic charr in August and September at river mouths along the west coast of Hudson Bay, in the Belcher Islands, and likely along the Quebec coast, but most of these people are local residents. Tourists who visit Kivalliq to sportfish generally do so at inland lakes where they catch trophy lake trout or Arctic grayling.

Table 14-2. Provincial/Territorial responsibilities for the management of recreational fisheries (from DFO 2001).

Province/Territory	Management Responsibilities
Nunavut	The Nunavut Wildlife Management Board is responsible for fishery allocations and advises DFO on conservation, fishery management, and science activities. Nunavut administers sportfish licensing under an Order-in-Council.
Quebec	The Province manages and licenses freshwater, anadromous, and catadromous species. The Federal Government manages other marine species.
Ontario and Manitoba	The Federal Government manages marine species in Ontario and Manitoba. The Provinces manage and license freshwater species.

Note: Because the federal Government has legislative authority for inland fisheries, all recommendations for amendments to regulations under the *Fisheries Act* (e.g., quotas, seasons, closed times, gear, etc.) are forwarded to Fisheries and Oceans to obtain Governor-in-Council approval.

There is some resident and non-resident angling at rivers near communities or commercial goose hunting camps along the Ontario coast (OMNR 1985). Brook trout, northern pike, walleye, yellow perch, lake trout, and lake sturgeon are the main species sought (OMNR 1985; Brousseau and Goodchild 1989). The sport fishery along the northern Manitoba coast is similar, with northern pike, brook trout, Arctic grayling, and walleye being the main species sought (McRae and Remnant 1995). Estimates of the total harvest are not available, but the sport harvest of estuarine and marine fishes is likely small.

Non-native sport fishing in western Quebec is confined mainly to lakes, where the principal species caught are walleye and northern pike (Roy 1989). There is little non-aboriginal sport fishing along the Quebec coast of James Bay, since much of the area is reserved for aboriginal use (i.e., category 2 lands) and non-aboriginals require band council permission in order to fish legally (F. Berkes, Univ. of Manitoba, Winnipeg, pers. comm.).

14.5 MAMMALS

Traditional subsistence harvests of mammals that use the waters or ice of the Hudson Bay marine ecosystem are important to the Aboriginal cultures and regional economy. These animals include belugas, narwhals, walruses, seals, Arctic foxes, and polar bears. Commercial whaling, particularly for bowhead and belugas, was instrumental in the European exploration and development of the region and dates back to the late 1600's in northern Hudson Bay. Whales are no longer harvested commercially, but bowhead populations and the eastern Hudson Bay beluga stock have not recovered from past commercial harvests and remain depleted. The commercial harvest of seal pelts from the region was largely eliminated by the 1982 European embargo on their import. There is a limited sport hunt for polar bears and walruses.

14.5.1 Beluga

Hunting regulations for belugas are implemented by DFO under the Marine Mammal Protection Regulations of the *Fisheries Act* (http://laws.justice.gc.ca/en/F-14/SOR-93-56/122456.html#rid-122537). These regulations prohibit unnecessary disturbance of belugas, and the killing of calves or females with calves. Indians or Inuit who normally reside adjacent to the tidal waters of Hudson Bay or James Bay are permitted to hunt belugas without a licence; non-native residents require a licence and can only hunt belugas for food for themselves and their family--belugas cannot be used for dog food. In the past, licences were issued to non-native hunters at Churchill on a case-by-case basis. Killing belugas solely for scientific purposes is not permitted, but Scientific Permits may be issued to permit sampling of subsistence kills and the export of samples for analysis. Churchill is a particularly important area for the scientific study of belugas because the whales are so accessible. Belugas were live-captured at Churchill for aquaria, beginning in 1967 (Moshenko 1990; P. Hall, DFO Winnipeg, pers. comm. 2004). Sixty-eight belugas were taken before the Minister of Fisheries and Oceans issued a moratorium on this practice in 1992.

Inuit, and to a much lesser extent Indians, have a tradition of harvesting belugas along the coasts of Hudson Bay and James Bay. Oil rendered from their blubber was burned in lamps, the nutritious fatty skin layer or muktuk was eaten, skin was sometimes used to make boots or tents, and the meat was eaten or used for dog food. The hunts had, and still have, important cultural and social value (e.g., Flaherty 1918; Degerbøl and Freuchen 1935; Doan and Douglas 1953; Johnson 1961; Brack and McIntosh 1963; Schwartz 1976; Welland 1976; Breton-Provencher 1979; Boulva 1981; Preston 1981; Finley et al. 1982; JBNQNHRC 1982, 1988; Gamble 1984, 1987a+b, 1988; Saladin d'Anglure 1984; Berkes and Freeman 1986; Reeves and Mitchell 1987a, 1989a+b; Strong 1989; Olpinski 1990; Baker et al. 1992; McDonald et al. 1997; Lesage et al. 2001; DFO 2002b).

There was no large-scale commercial whaling for belugas along the northern Hudson Bay coast of Quebec, but a sporadic, sometimes intensive and productive beluga fishery operated from the 1750's until about 1905 at estuaries along the southeast coast of Hudson Bay (Francis 1977; Finley et al. 1982; Reeves and Mitchell 1987a). It petered out before the Hudson Bay Company (HBC) established a post at Wolstenholme near Ivujivik in 1909, and posts at Inukjuak, Povungnituk, and Akulivik in the early 1920's. The main fisheries were conducted by the HBC at Grande rivière de la Baleine and Petite rivière de la Baleine, where the combined harvest was at least 8,294 whales in the 15 years between 1852 and 1868 (Reeves and Mitchell 1987a). Considering that the catch record is almost certainly incomplete, the "initial" (1853) population must have numbered at least 6,600 whales. There were also large, and perhaps separate, summer concentrations of belugas at the Nastapoka River and in Richmond Gulf (Finley et al. 1982; Reeves and Mitchell 1987a, 1989b). Small-scale whale fisheries were undertaken at all the posts until the late 1930s.

Most beluga harvesting in southeast Hudson Bay now takes place between June and October at the Nastapoka, Grande rivière de la Baleine, or Petite rivière de la Baleine estuaries, in Richmond Gulf, or near the communities (Figure 14-1;Table 14-3)(Schwartz 1976; Breton-Provencher 1979; Olpinski 1990; Lesage et al. 2001). Beginning in 1986, management plans were adopted by DFO in cooperation with Anguvigak for each of the Nunavik communities (Lesage et al. 2001; DFO 2002a). These plans are re-examined regularly. They include quotas for each community and seasonal closures (July) at the Nastapoka River (1991) and Petite rivière de la

Table 14-3. Beluga harvests from Hudson Bay and James Bay by communities in Nunavik and Kivalliq, 1990-2001. Sources listed below.

Community	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total	Average[1]
NUNAVIK (Quebec)														
Kuujjuarapik	8	12	16	12	22	14	15	11	14	14	8	15	**161**	**13**
Umiujaq	12	24	24	19	18	21	19	19	18	24	19	17	**234**	**20**
Inukjuak	11	20	16	13	19	20	22	21	18	19	35	25	**239**	**20**
Puvirnituk	22	50	22	23	23	36	38	33	36	27	29	50	**389**	**32**
Akulivik	9	18	16	16	20	18	15	24	17	22	12	33	**220**	**18**
Ivujivik	20	31	2	37	0	38	34	22	44	37	36	13	**314**	**26**
KIVALIQ (Nunavut)														
Arviat	70	25	nr[1]	23	32	3	100	100	nr	58	100	100	**611**	**61**
Chesterfield Inlet	20	20	nr	17	27	22	20	nr	nr	nr	1	25	**152**	**19**
Coral Harbour	67	125	nr	20	30	50	31	30	nr	50	35	25	**463**	**46**
Rankin Inlet	40	20	nr	14	29	88	48	48	nr	nr	45	35	**367**	**41**
Repulse Bay	20	13	9	12	28	35	20	nr	nr	4	0	10	**151**	**15**
Sanikiluaq	20	22	20	10	50	30	30	19	nr	32	21	0	**254**	**23**
Whale Cove	27	25	27	19	37	2	35	20	nr	nr	20	40	**252**	**25**

Sources: **Nunavut**: 1990 (DFO 1992b), 1991 (DFO 1993), 1992 (DFO 1994), 1993 (DFO 1995), 1994 (DFO 1996), 1995 (DFO 1997), 1996 (DFO 1999b), 1997-2001 (DFO unpubl. data); **Nunavik**: 1990-2000 (Lesage et al. 2001); 2001 (DFO 2002a).

[1] nr = no report, empty cell = no report to date. Averages do not consider either.

Baleine (1996). The hunters agreed to avoid killing mature females with calves and DFO further recommended that any hunt be directed toward adult males. The 1995-2000 management plans recommended an annual quota of 18 belugas for each for the eastern Hudson Bay communities in Nunavik (Akulivik, Puvirnituq, Inukjuak, Umiujaq, and Kuujjuarapik) and a quota of 25 belugas for Ivujivik, which harvests animals from Hudson Strait. During this period, the total harvests consistently exceeded the recommended quotas (Hammill 2001; Bourdages et al. 2002; DFO 2002a). The actual rate of removal of belugas from the populations may be substantially greater than the estimated harvests, due to under-reporting of the landed harvests and uncertainty about the rate of mortality among whales that are struck and lost (Hammill 2001; Bourdages et al. 2002; DFO 2002a).

A new management plan was implemented in 2001 (DFO 2002a). It recommended that the eastern Hudson Bay communities harvest no more than 30 animals from eastern Hudson Bay, 30 from James Bay and 65 from Hudson Strait. The intent was to shift some of the harvesting effort from the eastern Hudson Bay belugas into James Bay (DFO 2002b). The actual harvest of eastern Hudson Bay belugas may be greater, as they may also be vulnerable to harvest by Sanikiluaq and communities in Hudson Strait (de March and Postma 2003). Inuit hunters have been urged to avoid the river mouths concentrations. There is concern that continued harvesting and exposure to environmental modification threaten this region's beluga stock in its depleted state (Reeves and Mitchell 1989b; Woodley and Lavigne 1991; Bourdages et al. 2002; DFO 2002a). COSEWIC considers belugas in eastern Hudson Bay to be threatened (Reeves and Mitchell 1989b).

Historically, belugas in James Bay were harvested for subsistence and to supply the coastal HBC posts, but there was not the same intense commercial harvest as occurred in Hudson Bay (Gordon 1923; Schwartz 1976; Reeves and Mitchell 1987). Currently there is no regular harvesting of belugas in James Bay (Gosselin et al. 2002). Residents of Chisasibi and Wemindji on the Quebec coast of James Bay once harvested belugas on a regular basis (JBNQNHRC 1982). Recommended annual harvest levels, based on estimates of past harvests, are 2 and 1 belugas for these communities respectively.

Reeves and Mitchell (1989a) did not find references to commercial whaling for belugas along the Ontario coast of Hudson Bay in HBC journals from Winisk and Ft. Severn. The ready availability of fish for dog food and a regular supply of oil from the posts at York Factory and Churchill may have eliminated the need for whaling to supply the posts. The cost of maintaining the whaling boats and trained personnel--there being no Inuit, particularly if there were relatively few whales, may also have made whaling uneconomic.

Reeves and Mitchell (1989a: pages iv-v) summarized the exploitation of belugas in western Hudson Bay, which began in 1688 and ended in 1970, as follows:

> *"The whale fishery at York [Hayes and Nelson Rivers by the Hudson Bay Company] was never established on the same scale as the Churchill fishery. In spite of their abundance in the Nelson estuary, whales proved difficult to catch there. Boat whaling and netting were tried in both the Hayes and Nelson rivers, but the most popular method of obtaining whales at York was to purchase them from Indians who whaled from "stands" erected in the intertidal zone. Much of the catch was used to feed dogs, and relatively little oil was exported.*
>
> *Churchill was the focal point for the HBC's [Hudson Bay Company's] whaling activities in western Hudson Bay. Boat whaling in the Churchill River achieved only modest results during the eighteenth century, when the highest documented catch for any decade was about 400 whales (1770-79). At the beginning of the nineteenth century effort shifted to the Seal River, where Inuit whaled from kayaks in the company's behalf. Oil returns from the Seal River contributed significantly to Churchill's exports during much of the nineteenth century, but this contribution was severely limited by problems associated with transporting the blubber from the hunting site to the factory. More than 500 whales were taken at the Seal River in some decades (1820s, 1840s, 1850s). The heyday of HBC whaling in the Churchill River began in the early 1880s, by which time the Seal River hunt was no longer important. More than 1300 whales were taken at Churchill through the first two decades of the twentieth century.*

> *By the 1930's, the HBC had essentially abandoned its whaling efforts at Churchill and York. In the late 1940s a Manitoba company built a whaling plant at Churchill and began a commercial operation that lasted until 1968. The catch of more than 4500 whales in the first decade of this operation (see Sergeant 1981) was over three times higher than the documented HBC catch at Churchill and York, combined, in any previous decade.*
>
> *A recent population estimate of at least 17,000 white whales [belugas] in western Hudson Bay suggests that HBC whaling at York and Churchill had no serious long-term consequences for the stock. The fishery from 1949 to 1968 was much more intensive, and the large current size of the population may be taken to indicate that the stock has recovered during the 20 years since the Churchill fishery closed, that the population in the 1940s was very large, or both. The population of white whales in western Hudson Bay appears not to have experienced the kind of depletion from overhunting that has been demonstrated for the populations in Cumberland Sound, Ungava Bay and (possibly) eastern Hudson Bay."*

Small-scale commercial harvests for belugas were also conducted at Arviat and Whale Cove in the early 1960's (Brack and McIntosh 1963; Reeves and Mitchell 1989a; Baker et al. 1992). Their main aim was to provide a reliable local food supply for local Inuit. Some beluga meat was canned at various points along the coast during the summers of 1961-64, and maqtaq (muktuk) and meat were processed at a fish plant that was established at Daly Bay in 1964 and relocated to Rankin Inlet in 1966 (Lantz and Iredale 1972; Carder and Peet 1983). Belugas for the plant were harvested near Whale Cove, where they were butchered, frozen, and then towed in a freezer barge to Rankin Inlet. Product demand declined steadily and, in 1970, when mercury levels of 0.5 ppm (wet wt) were found in the whale meat the commercial harvest was stopped (Sergeant and Brodie 1975; Carder and Peet 1983).

Sport hunting of belugas was encouraged at Churchill and in the Whale Cove-Arviat area from the late 1940s through the 1960s (Frick 1968; Reeves and Mitchell 1989a). The hunts were banned in 1973 for humane reasons (Sergeant and Brodie 1975).

The Kivalliq communities have never had quotas on their beluga harvests and, to date, there is no Community Based Management of the harvest as there is for narwhals at Repulse Bay (P. Hall, DFO Winnipeg, pers. comm. 2004). Data on the harvests from 1990 through 2001 are provided in Table 14-3. Most beluga harvesting from western and northern Hudson Bay now takes place between July and September near the Kivalliq communities (Gamble 1984, 1987a+b, 1988). The species is hunted along the west coast of Hudson Bay and into Chesterfield Inlet as far as Ekatuvik Point from July through September (Brack and McIntosh 1963; Welland 1976). The greatest catches at Arviat are in July and August, at Whale Cove and Rankin Inlet in August, at Chesterfield Inlet and Repulse Bay in August and September, and at Coral Harbour in July through September (Sergeant 1973; Gamble 1984, 1987a+b, 1988). Hunters from Coral Harbour occasionally harvest belugas at the ice edge in June and from October through February.

In 2002, Quebec Inuit, unable to satisfy local demand under the harvest quotas, approached the Kivalliq Wildlife Board with a view to purchasing *maqtaq* (Tyrrell 2003). The Arviat Hunters and Trappers Organization purchased 2220 kg (5000 lbs) of *maqtaq* from local families and resold it to communities in Quebec. Concerns were expressed within Arviat regarding the ramifications of commercialising the harvests; in particular, whether the population might decline or a quota might be imposed. A similar request for *maqtaq* was received in 2003.

14.5.2 Narwhal

Narwhals historically provided important staples in the traditional subsistence economy of northwest Hudson Bay. Hunting and sharing of its proceeds continue to be of great social and cultural significance, particularly for Repulse Bay (Reeves 1992a+b, 1993a; Gonzalez 2001). Narwhals are harvested mainly for their *maqtaq* and ivory. The *maqtaq* is consumed locally or traded to other Inuit communities. It is a highly valued food and demand often exceeds supply. The ivory is a byproduct of the hunt that commands high prices and is marketed internationally.

The ivory tusk of males is a valuable economic commodity and an important source of cash income for some coastal communities (Reeves 1992a+b; Gonzalez 2001). The international value of the tusk gives hunters a strong incentive to hunt males with large tusks. This can strongly influence the nature and intensity of the hunt. A ban on the importation of narwhal ivory by the European Economic Community (EEC) caused the price of narwhal ivory to plummet in 1983/84 but it has since recovered due to the strong demand for narwhal ivory in Japan. Market interventions and price instability have had serious ramifications for Inuit communities in the past and are likely to affect the cost and rewards of narwhal hunting in the future as well (Reeves 1992b).

Hunting regulations for narwhals are implemented by DFO under the *Fisheries Act* by the Marine Mammal Regulations. Under these Regulations, only Inuit can hunt narwhals and there is a quota on the number of animals that can be harvested by each community (Table 14-4). These quotas were set initially through negotiation with the communities, and based on historic harvesting levels (Strong 1988). The community quotas are tracked through a tag system. Hunters are required to attach a Marine Mammal Tag to the tusk or carcass of landed narwhal. For many years, the hunters have requested changes to the management system for narwhals, with the result that a Community-Based Management (CBM) system is now being tried at Repulse Bay and other communities in Arctic Canada (DFO 1998a+b; Gonzalez 2001). This 3-year pilot program was reviewed in 2003 and extended for a further 5 years, and an integrated management plan is being developed (M. Wheatley, NWMB Iqaluit, pers. comm. 2003).

Table 14-4. Annual landed harvest of narwhals from the Hudson Bay population, 1990 to 2001. Sources listed below.

	Historical Quota	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total	Average
Cape Dorset	10	0	16	0	0	1	0	0	0	0	0	0	1	**18**	**1.5**
Chesterfield Inlet	5	0	0	0	0	0	0	0	0	3	5	3	2	**13**	**1.1**
Coral Harbour	10	0	0	0	1	0	10	10	9	4	0	0	0	**34**	**2.8**
Kimmirut (Lake Harbour)[1]	10	0	0	0	0	0	0	0	0	0	0	0		**0**	**0**
Repulse Bay	25[2]	17	3	20	13	5	4	10	35	18	156	49	100	**430**	**33.1**
Rankin Inlet	10	0	0	0	0	0	6	7	0			7	3	**23**	**2.3**
Whale Cove	5	0	0	0	0	0	0	0	1				2	**3**	**0.3**
HB TOTAL		**17**	**19**	**20**	**14**	**6**	**20**	**27**	**45**	**25**	**161**	**59**	**108**	**521**	**41.1**

Sources: 1990 (DFO 1992b), 1991 (DFO 1993). 1992 (DFO 1994), 1993 (DFO 1995), 1994 DFO1996), 1995 (DFO 1997), 1996 (DFO 1999b), 1997-2001 (DFO unpubl. data).

[1] Community names that were used in the past are enclosed in brackets.

[2] The Repulse Bay "quota" was replaced in 1999 by the community-based management program. In 2002 the community harvest limit was 72 narwhals.

nr = no report, blank space= report may be forthcomig.

To qualify for community-based management, local HTOs must first develop hunting rules or by-laws to address the conservation and management of the narwhal population, the reduction of waste, hunter education, and safety. Participating HTOs also agreed to collect and report the number of narwhals landed annually as well as information on the number of narwhals that were wounded and escaped, and the number killed but not landed. Communities that have qualified for CBM no longer hunt under their historic quota; however harvest limits are in place for each of the participating communities and the landed catch continues to be tracked by the tag system.

The Hudson Bay narwhals are hunted mainly by residents of Repulse Bay and sometimes by residents of 6 other communities Table 14-4). Most animals are harvested in July and August (Gamble 1988). The number of narwhals killed during these hunts is higher than the number landed. Information about seasonality of these loss rates in Hudson Bay is lacking, but loss rates in the High Arctic are typically highest at the floe edge and lowest during the open water hunt (Roberge and Dunn 1990). Loss estimates from the community-based management hunts in 1999 through 2001 suggest that on average at least 17 (SD = 5; killed and lost only) and perhaps as many as 50 (SD = 15; killed and lost plus struck and escaped) animals are lost for every 100 landed (Table 14-5). The collection of struck and lost data is a key contribution of the community-based management program to improving estimates of hunting mortality.

Table 14-5. **Landed harvest and loss and mortality estimates for the harvest of narwhals from the Hudson Bay population by Repulse Bay under community-based management in 1999 to 2001 (DFO unpubl. data).**

Year	Narwhals landed (#)	Loss estimate (# of animals)		Mortality estimate (# of animals)		Loss rate (% of landed harvest)	
		Killed and lost	Wounded and escaped	minimum	maximum	minimum	maximum
1999	156	30	68	186	254	19	63
2000	49	5	9	54	63	10	29
2001	100	21	38	121	159	21	59

There is strong economic pressure to land tusked males despite a preference for the *maqtaq* of juvenile narwhals (Reeves 1992a). This selection is more successful during on-ice hunts in the spring when the narwhals are shot at close range and the tusk is clearly visible, than during open-water hunts (Reeves 1976). Hunter preference for large-tusked males may lead to underestimates of numbers of females killed, given that hunters may expend more effort to retrieve male carcasses (Weaver and Walker 1988; Roberge and Dunn 1990).

Lack of reliable age data for narwhals prevents accurate prediction of reproductive and survival rates and thereby sustainable hunts. DFO (1998a) has recommended a precautionary hunting rate of 2% (DFO 1998a).

Landings from the Hudson Bay population increased from an average of 22 (SD = 9.7) whales per year over the period 1979-1998 to an average of 109 (SD = 51) whales per year over the period 1999-2001 (Table 14-4). Unusually large numbers killed by Repulse Bay hunters are responsible for this increase. Repulse Bay may have removed between 5.2 and 6.9% of the Hudson Bay narwhal population in 1999 based on the 2000 survey estimate of 1780 narwhals in the Hudson Bay population (P. Richard, DFO Winnipeg, pers. comm. 2002), assuming that up to 50% of the whales may have been submerged and therefore missed by the survey, assuming an annual rate of increase of 4%, and using the community-based mortality estimates (186-254 narwhals; Table 14-5). Indeed, population mortality in 1999 may have been higher due to predation by killer whales (Gonzalez 2001). The effects on population structure of this simultaneous removal by hunters, who prefer tusked males, and killer whales, that prefer non-tusked narwhals (Gonzalez 2001), are unknown. Hunters from the community may also have removed between 3.6 and 4.7% of the population in 2001, when they filled the community-based management limit of 100 narwhals.

The Hudson Bay narwhal population is unlikely to support the rates of removal seen in 1999 and 2001 over the long term, unless the natural rate of increase is greater than 5% per year (Stewart 2004a). In 2002, the community-based management program responded to this concern by reducing the annual harvest limit for Repulse Bay from 100 to 72 narwhals. If the population is smaller than the estimate derived in 2000 (i.e., including a correction for submerged animals) or the natural rate of increase is less than 4%, then the population would be at risk if communities that hunt narwhals from the Hudson Bay population approach their annual limits on a regular basis.

14.5.3 Bowhead

Hudson Bay Inuit have a long tradition of harvesting bowhead whales. Indeed, Ellis (1748 in Reeves et al. 1983) found a bowhead carcass with an Inuit harpoon in it floating between Cape Southampton and Mansel Island in 1746. The ancestors of present day Inuit developed specific tools and techniques to hunt bowheads and used all parts of the harvested animals (NWMB 2000). Later, after the arrival of European and American whalers, they participated in the commercial harvests until the whale populations were depleted (Ross 1974, 1975; 1979). Many Inuit still have a strong interest in harvesting bowheads for food and as part of their cultural heritage (NWMB 2000).

Whalers knew the bowhead as one of the "right" whales because of its enormous store of blubber, large quantity of baleen--the long horny plates used by the whale to filter food from the water, and tendency to float when dead (Mansfield 1985). Fine oil was rendered from the blubber before mineral oils became readily available, and a variety of products that required strength and flexibility were made from the baleen before the advent of spring steel and plastics (Leatherwood and Reeves 1983). The baleen was also known as whalebone or bone.

Commercial whaling for bowhead was initiated in 1765 by Churchill-based sloops of the Hudson Bay Company (Ross 1979). The fishery produced only 6 whales in 9 voyages and was abandoned in 1772. American vessels operating from ports in New England began the second, far more intensive period of whaling, in 1860. Between 1860 and 1915, American and British whalers killed an estimated 566 whales in northwest Hudson Bay, and very nearly extirpated bowheads from the region (Ross 1974, 1979; Mitchell and Reeves 1982; Reeves et al. 1983). There are no records of bowheads having been hunted in James Bay or southeast Hudson Bay but some whales were harvested in the Ottawa Islands (Flaherty 1918; Newspaper Clipping in PAC, MG 29, A58, Vol 8., File 5 in Reeves and Mitchell 1987).

While the large-scale whale fishery collapsed before 1916, some shore-based hunting for bowheads has continued. The hunts are usually by Inuit but sometimes with the involvement of local white residents (Mitchell and Reeves 1982; NWMB 2000). Between 1919 and 1979, about 32 bowheads from the Hudson Bay/Foxe Basin population were killed or struck and lost (i.e., 23 reported by Mitchell and Reeves 1982 in their Table 1; 9 reported by NWMB 2000:74). Since 1979, anyone hunting bowheads in Canada has required a licence from the Minister of Fisheries and Oceans (DFO 1999a). Strong arguments have been made against permitting the harvest of bowhead in the eastern Canadian Arctic until the populations are shown to have recovered to a high proportion of its initial level (Mitchell and Reeves 1982).

There were no licensed hunts between 1979 and 1996 but, in 1985, hunters at Arviat shot at a bowhead (R. Stewart, DFO, Winnipeg, pers. comm.). It is not known whether they killed the animal, but a carcass did wash ashore nearby soon afterward. In 1994, a female young-of-the-year calf from the Hudson Bay/Foxe Basin population was landed illegally near Iglulik (DFO 1999a).

A limited subsistence hunt for bowhead resumed in Nunavut in 1996 (DFO 1999a). The hunt is co-managed by the Nunavut Wildlife Management Board with advice and support from the Canada Department of Fisheries and Oceans (DFO). Hunting regulations are implemented by DFO under the *Fisheries Act* and its Marine Mammal Regulations. The sustainable harvest level for the Hudson Bay/Foxe Basin bowhead population has been estimated by DFO at about 1 whale every 2 years (i.e., potential biological removal = 0.6; DFO 1999a). However, this method of estimation may not be suitable for managing the direct exploitation of small populations (Finley 2001). In 1996, hunters from Repulse Bay were licensed to hunt a bowhead and killed an adult male, which was not secured and sank (Colbourne 1996; Kringayark 1996; van Rassel 1996). The carcass resurfaced 46 hours later, by which time the meat was unfit for human consumption. Some of the *maktaq* was eaten but much of the whale was left to rot on the shore. In 2000, Coral Harbour harvested a juvenile male bowhead from Hudson Bay, and in 2002 Igloolik/Hall Beach harvested a female from Foxe Basin (B. Dunn, DFO Winnipeg, pers.

comm.). The whales from both hunts were secured. The *maktaq* was eaten, the meat was fed to the dogs, and bone and baleen were used for carving.

14.5.4 Arctic Fox

Arctic foxes are harvested for their luxurious fur from November through April, mainly by Inuit but sometimes by Cree (Table 14-6) (JBNQNRC 1982, 1988; Gamble 1988; J. Pattimore, pers. comm.). The fur is used to make decorative clothing or sold. The proportion of the fox harvest that is taken on the sea ice is unknown.

Table 14-6. Estimated mean annual subsistence harvests of Arctic foxes by communities around Hudson Bay and James Bay. Sources listed below.

Community	Period	Source	Hunters	Human Population[1]	Arctic fox
QUEBEC					
Waskaganish	1975-6 to 1978-9	1	Cree	999	4
Eastmain	1975-6 to 1978-9	1	Cree	319	3
Wemindji	1975-6 to 1978-9	1	Cree	665	3
Chisasibi	1975-6 to 1978-9	1	Cree	1603	80
	1976-80	2	Inuit	42	2
Kuujjuarapik	1975-6 to 1978-9	1	Cree	373	10
	1976-80	2	Inuit	558	121
Umiujaq	1990	3	Inuit	-[4]	-
Inukjuak	1976-80	2	Inuit	530	1429
Puvirnituq	1941-72	4	Inuit	-	-
Akulivik	1976-80	2	Inuit	140	340
Ivijivik	No data		Inuit	-	-
ONTARIO					
Moose Factory/ Moosonee	1990	5	Cree	3000	9
Fort Albany	1990	5	Cree	625	0
Kashechewan	1990	5	Cree	1000	27
Attawapiskat	1990	5	Cree	1214	66
Peawanuck	1990	5	Cree	227	3
Fort Severn	1990	5	Cree	332	133
MANITOBA					
Churchill[2]	May 1995-Apr. 1996	7	not stated		
NUNAVUT[3]					
Arviat	1983-85	6	Inuit	1022	1190
Whale cove	1982, 1984-5	6	Inuit	188	102
Rankin Inlet	1982-85	6	Inuit	1109	
Chesterfield Inlet	1983-85	6	Inuit	249	128
Coral Harbour	1984-85	6	Inuit	429	488
Repulse Bay	1982-85	6	Inuit	352	296
Sanikiluaq	1980-84	8	Inuit	383	528
TOTAL					**4433**

Sources: 1 = JBNQNHRC 1982, 2 = JBNQNHRC 1988, 3 = INRS-Urbanisation 1990, 4 = Smith 1975, 5 = Berkes et al. 1992, 6 = Gamble 1988, 7 = McRae and Remnant 1997; 8 = J. Pattimore, pers. comm.

[1] Populations are for the Aboriginal communities except in Nunavut, where community populations ca. 1985 are listed from the 1985 Explorers Guide. The Quebec Cree populations are 5-year means 1974-5 to 1978-79 (JBNHRC 1988); the Quebec Inuit populations are from 1976 (JBNQNHRC 1982); Ontario Cree populations are from 1990, except Attawapiskat (1989) (Berkes et al. 1995).

[2] Churchill data are reported rather than estimated harvests from 67 of 182 people identified as domestic harvesters.

[3] Nunavut means based only on years with complete harvest records. [4] Dashes indicate no data; blank cells indicate no harvest reported

[5] 23 years of records

14.5.5 Polar Bear

Inuit and Cree hunt polar bears in Hudson Bay and James Bay (e.g., Johnston 1961; Jonkel et al. 1976; Manning 1976; Welland 1976; JBNQNHRC 1982, 1988; Gamble 1984, 1987a+b, 1988; OMNR 1985; Vandal 1987; Vandal and Adams 1988, 1989). Most of the bears are shot between September and May (Figure 14-1), when they have their thick winter pelage; females with cubs or in dens are avoided. The bears are hunted mainly for their hides, which are sold for rugs or used to make winter clothing. The meat is eaten on occasion but must be properly cooked to avoid contracting trichinellosis (Urquhart and Schweinsburg 1984). Polar bear liver has very high vitamin A content and can be toxic to humans if eaten (Lewis and Lentfer 1967; Leighton et al. 1988). There is a strong demand for polar bear gall bladder in the Orient as an aphrodisiac.

Regulations governing polar bear harvests in the various jurisdictions around Hudson Bay and James Bay are summarized in (Table 14-7). Lunn et al. (2002a) described these regulations in detail. Boundaries of the Foxe Basin (FB), Western Hudson Bay (WH), and Southern Hudson Bay (SH) polar bear populations/management areas are shown in Figure 9-6

The current sustainable harvest of the Western Hudson Bay population is estimated to be 55 bears, which is divided between Nunavut (28) and Manitoba (27)(Calvert et al. 2002). There is no open season for hunting polar bears in Manitoba (Lunn et al. 2002a). Part of the Manitoba quota is used for bear control in and around Churchill (8 tags); the balance (19 tags) is loaned to and administered by the Government of Nunavut.

Memoranda of understanding that are based on a flexible quota system for polar bear harvests are in effect between the Government of Nunavut and the Nunaut communities that hunt polar bears in and around Hudson Bay. These documents specify quotas and other aspects of harvest management. The flexible quota system is designed to provide a "self directed" quota system that keeps the kill within the sustainable yield, while allowing each community the flexibility to harvest polar bears in a manner that suits their needs (see Appendix 1 of Lunn et al. 1998). To accrue the economic benefits of big game sport hunting some Kivalliq communities set aside a portion of their quota to be used by outside sport hunters.

Harvesting along the northern Ontario coast is restricted to hunting by Treaty Indians (Lunn et al. 2002a). Under the *Fish and Wildlife Conservation Act*, which replaced the *Game and Fish Act* on 1 January 1999, the polar bear is classified as a furbearer (Ont. Reg. 669/98). As such, there is no open season for polar bear hunting but authorization is given to some native trappers, who possess a valid trapping licence, to harvest limited numbers of bears. Authorization is required from Ontario Ministry of Natural Resources to sell any polar bear pelt. The permissible annual kill is limited to 30 bears that can be killed and sold legally in the Moosonee District, of which hunters from Fort Severn can harvest 12, hunters from Peawanuck (Winisk) 12, Attawapiskat 4, Kashechewan 1, and from Fort Albany 1 (OMNR 1985). Over the period 1970-71 to 1989-90, on average 20.8 bears were killed annually in Ontario; over the period 1990-91 to 2002-03, the average annual kill dropped to 8.5 bears (M. Obbard, OMNR pers. comm. 2004). While the current levels of harvest are believed to be sustainable, the Southern Hudson Bay population would be over harvested if Ontario hunters took the number of polar bears to which they are "entitled" (see Table 9-2).

Under the James Bay and Northern Quebec Agreement only Inuit and Cree can harvest polar bears along the Quebec coast (Lunn et al. 2002a). Guaranteed harvest levels were established under the Agreement based on the observed polar bear harvest between 1975 and 1980 (see JBNQNHRC 1982, 1988). These levels were agreed to by both Inuit and Cree and can be taken as long as the principle of conservation is respected. The current harvest levels appear to be sustainable. An agreement has been negotiated to implement a hunting season (September-May), protect females with cubs, and prohibit hunting of polar bears in their summer refuge. Polar bears that are harvested from the Quebec coast of James Bay and Hudson Bay are taken mostly from the Southern Hudson Bay population by Inuit residents of Inukjuak and Kuujjuarapik (Vandal 1987; JBNQNHRC 1988; Vandal and Adams 1988, 1989). Cree at Wemindji harvest a polar bear in some years, and those at Chisasibi harvest a few bears most years (JBNQNHRC 1982). Hunters from Sanikiluaq, in Nunavut, have historically harvested the greatest numbers of bears from the Southern Hudson Bay population (Figure 9-1)(Jonkel et al. 1976).

Table 14-7. Summary of regulations covering polar bear management in Canada as of 31 December 2000 (modified from Lunn et al. 2002a).

	JURISDICTION			
CATEGORY	**Manitoba**	**Nunavut**	**Ontario**	**Quebec**
Hunting	Closed	Season varies between Polar Bear Management Areas; longest 1 Aug-31 May; shortest 1 Jan-31 May	Closed	No sport hunting
Who can hunt	A person who posesses a ministerial permit	A person who possesses a tag. Tags are distributed by the HTOs	Permissible kill by Treaty Indians	Inuit and Indians
Quota	27 (19 on loan to Nunavut; 8 retained for Polar Bear Alert Program)	By settlement; 2000-2001 quota is 395	Permissible kill of 30 (by restricting sales over 30)	None
Females and cubs protected by law	Yes	Yes	No	Yes
Bears in dens protected by law	Yes	Yes. Also includes bears constructing dens.	No	Yes
Proof of origin of untanned bear	Documented proof	Tag on hide and export permit.	Seal on hide, proof of origin required on imported hides	Seal on hide
Export permit required and cost (out of province or territory of origin)	Required; no cost	Required; no cost. There is a $750.00 Trophy Fee for non-residents and non-resident aliens.	Required; no cost	Required; no cost
Export permit out of Canada	Required by CITES for all polar bears or parts thereof exported out of Canada; obtained in province or Territory exporting from.			
Scientific Licences	Discretion of Minister	Discretion of Superintendent of Wildlife	Discretion of District Manager	Discretion of Minister
Selling of hide by hunter	Subject to conditions of ministerial permit	Yes, must have tag attached	Must be sealed by Ministry staff	Must be sealed; fee 5% of average value of last 2 years
Basis of Regulation	The Wildlife Act; reclassified as a protected species in 1991	Wildlife Act and Regulations	Fish and Wildlife Conservation Act, 1997 (Statutes of Ontario, 1997, Chapter 41)	Wildlife Conservation and Management Act 1983; Order in Council 3234-1971; Bill 28-1978 (James Bay Agreement)
Fur Dealer Authority	$25.00 general; $25.00 travelling	$200.00 Fur Dealer's Licence for first year, $100.00 each year after	$28.00 licence	$335.00 licence
Taxidermy	$30.00 licence	$100.00 Taxidermist Licence for first year, $50.00 for each year after	See Tanner's Authority	See Tanner's Authority
Tanners Authority	$30.00 licence	$100.00 Tanner's Licence for first year, $50.00 for each year after	Fish and Wildlife Conservation Act 1997 ($28.00 licence)	$256.00 Tanner's Licence
Live Animal Capture	Ministerial Permit	$5.00 licence to capture live wildlife	Ministerial Permit	Ministerial Permit
Live Animal Export	Ministerial Permit	Licence to Export Live Wildlife, $3000/polar bear	Ministerial Permit	Ministerial Permit

Data on the mean annual kill from the three polar bear populations that inhabit Hudson Bay and James Bay are summarized over the 5-year period 1995-1996 to 1999-2000 in Table 9-2. Data are also presented on the proportion of females taken. The current harvest from each of the populations is believed to be sustainable (Lunn et al. 2002a).

14.5.6 Walrus

Walruses are an important part of the Inuit marine mammal harvest in Hudson Bay, but have rarely been harvested from James Bay since ca. 1934 (Fleming and Newton 2003). Inuit and Indian natives of Canada can kill up to four walruses per year without a licence, except where community quotas limit annual catches; non-natives require a licence under the Marine Mammal Regulations or Aboriginal Communal Fishing Licence Regulation of the *Fisheries Act* to hunt walruses (DFO 2003). Since 1980, Coral Harbour has had an annual harvest quota of 60 walruses and Sanikiluaq of 10 walruses (Strong 1989). The quota system is under review by the Nunavut Wildlife Management Board, which is considering new ways of managing the walrus hunt (Stewart 2002). There are two putative stocks of walruses in Hudson Bay, the Hudson Bay/Davis Strait Stock, and the South and East Hudson Bay Stock (see also Section 9.8).

Communities along the west coast of Hudson Bay harvest walruses from the northern Hudson Bay portion of the Hudson Bay/Davis Strait Stock (Figure 9-9). These harvests increase from south to north and hunters often have to travel north into the Coats Island area to find walrus herds (Table 14-8). There are no recent reports of walruses being harvested at Churchill, Manitoba; they are rarely harvested at Arviat, irregularly at Whale Cove, and more commonly further north (Gamble 1988, Strong 1989; Fleming and Newton 2003). Timing of the harvests varies between communities. All of the communities harvest animals at the ice edge but the largest harvests are typically taken during the open water season in the Repulse Bay (September-October) and Coral Harbour-Coats Island (July-September) areas (Gamble 1984, 1987a+b, 1988).

Table 14-8. Walrus landings from stocks in Hudson Bay, by community, from 1993 through 2002. Landings from sport hunts are included in these totals. Sources listed below.

Community	Quota	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	1999/00	2000/01	2001/02	2002/03
HUDSON BAY/DAVIS STRAIT STOCK											
Kivalliq											
Arviat	-	0	0	0	0	nd	0	2	1	nd	nd
Chesterfield Inlet	-	6	0	3	12	nd	0	nd	5	nd	nd
Coral Harbour	60	55	31	48	12	nd	9	8	1	nd	nd
Rankin Inlet	-	4	2	6	12	nd	12	nd	7	nd	0
Repulse Bay	-	25	8	0	2	0	0	2	1	nd	0
Whale Cove	-	2	0	0	0	nd	0	0	0	nd	1
Nunavik											
Ivujivik	-	33	nd	20	7	23	1	7	5	14	10
Akulivik	-	1	9	nd	3	9	10	3	3	6	14
Puvirnituq	-	12	3	nd	4	6	0	4	6	6	13
SOUTH and EAST HUDSON BAY STOCK											
Sanikiluaq	10	nd	0	nd	nd	4	nd	1	0	0	15
Kuujjuarapik	-	0	0	0	0	2	0	1	0	0	0
Umiujaq	-	1	0	0	0	0	0	0	0	0	0
Inukjuak	-	nd	5	10	11	5	8	0	0	0	0

Sources: Brooke 1997; DFO 1995, 1996, 1997, 1998; D. Baillargeon, DFO, pers. comm. 2003; I. Itorcheak, DFO pers comm. 2003.

While walruses are harvested year-round by hunters from Coral Harbour, with the largest harvests typically taken during the open water season (Gamble 1988), residents participating in the traditional knowledge study of Hudson Bay indicated that they eat walrus in January, February and April (Fleming and Newton 2003). This apparent discrepancy may be related to the consumption of aerobically fermented walrus meat, called *igunak* (R. Stewart, DFO Winnipeg, pers. comm.). This process involves sewing walrus meat into a walrus skin bag, burying it on the beach, and then recovering and eating the contents after they have fermented and aged. Care must be taken to ensure that the meat does not ferment anaerobically, for example in sealed plastic bags, to avoid botulism (Proulx et al. 1997, 2002).

Residents of Puvirnituq, Akulivik, and Ivujivik regularly harvest walruses from the Hudson Strait portion of the Hudson Bay/Davis Strait Stock (JBNQNHRC 1988; Olpinski 1990; Brooke 1997). Most animals are killed during the open water season, often in September and October, near Nottingham and Salisbury islands (Olpinski 1990; Brooke 1997).

Hunters from Inukjuak, Kuujjuarapik, Umiujaq, and Sanikiluaq harvest walruses from the South and East Hudson Bay Stock (Table 14-8). Kuujjuarapik and Umiujaq harvest the occasional walrus in some years, typically along the Hudson Bay Arc coast, while Sanikiluaq and Inukjuak harvest a few walruses on average each year (JBNQNHRC 1988; Strong 1988; Olpinski 1990, 1993; Portnoff 1994). Historically, walruses in southeastern Hudson Bay and James Bay were hunted mainly during the open water season at their haulouts (Twomey 1939; May 1942; Manning 1946, 1976; Freeman 1964; Olpinski 1990; Reeves 1995a; Fleming and Newton 2003) (Figures 9-10 and 9-11). They were also killed in winter and spring at the floe edge or in spring as they slept on floating ice pans. Most recent hunting in this region has taken place in late summer and fall (September and October) at the Sleeper Islands ((Figure 14-1) (Manning 1976; Schwartz 1976; Olpinski 1990, 1993; Portnoff 1994; Brooke 1997; Fleming and Newton 2003). In 1992 and 1993, hunters from Inukjuak visited the Ottawa Islands where they failed to locate walruses, before travelling to the Sleepers for successful hunts (Olpinski 1993; Portnoff 1994). Cree living around James Bay and southern Hudson Bay seldom travel offshore to hunt walruses (Johnson 1961) but harvested them occasionally in the past (Fleming and Newton 2003).

NWMB approval is required to transfer individual hunting rights to non-beneficiaries wishing to hunt walruses for sport. Sport hunts for walruses have been approved annually since 1996 in the Coral Harbour area (P. Hall, DFO, Winnipeg, pers comm. 2003). These hunts harvested 1 animal in 1996/97, 5 in 1997/98, 2 in 2001/02, and 2 in 2002/03. Repulse Bay was approved to conduct sport hunts for walrus in 2002/03, but none were landed.

Walruses are harvested mainly for their ivory tusks, which are either sold or carved for sale, and for their meat, which is eaten or fed to the dogs (Freeman 1964; Schwartz 1976; Born et al. 1995). They are harvested and eaten on a seasonal basis depending upon availability, which varies among communities (Fleming and Newton 2003). For example, they are typically eaten in the fall in the Belcher Islands; during the boating, fall, and early winter seasons in Repulse Bay (i.e., mostly in September and October—see Gamble 1988); and yearround but mainly in late summer and early fall at Coral Harbour (i.e., July-September—see Gamble 1988).

In the past, Inuit used ivory to construct harpoons, make toggles and handles, shoe sledges, and for protective edges on kayak paddles. The thick skin was used to make summer tents. Molluscs in the walrus' stomach are considered a delicacy by area Inuit (H.E. Welch, DFO, Winnipeg, pers. comm. 1991). Indians occasionally harvested walruses in the past to feed dog teams, and made rope from the tough hide (Fleming and Newton 2003). They only ate walruses when there was no other food. Both Inuit and Cree participants in the Hudson Bay Programme traditional knowledge studies reported that they "*knew walrus better when they were still using dog teams*". This is indicative of changing harvest patterns.

Walrus meat must be well cooked as it sometimes contains the parasite, *Trichinella nativa*, which causes trichinellosis (Pozio et al. 1992; Serhir et al. 2001). This parasite has been identified in earlier literature as *T. spiralis* (e.g., Born et al. 1982). Walrus-related outbreaks of this disease were reported at Inukjuak in 1997, and in Repulse Bay in 2002, and the problem is widespread in the Canadian eastern Arctic (Serhir et al. 2001; Hill 2003). A program is in place in Nunavik to prevent further outbreaks, by screening samples from harvested walruses before each animal is eaten (Proulx 2002). Similar testing is planned for Nunavut at a laboratory in Rankin Inlet (Hill 2003). There is serological evidence that some walruses in the Igloolik area may have sporadically been infected with the bacterium *Brucella* sp., which can infect humans (Nielsen et al. 1996). Inuit recognize the livers of seal-eating walruses by their "cooked appearance" and avoid eating them (Fleming and Newton 2003). The livers of these walruses are inedible, as they contain toxic concentrations of Vitamin A (Bruemmer 1977; Reeves 1995a).

COSEWIC currently is reassessing the status of the walrus populations in Hudson Bay (Stewart 2004b). Too few data are available to determine whether there are trends in the size of the Hudson Bay/Davis Strait or South and East Hudson Bay populations, or whether current harvests are sustainable. Observations that they have abandoned a number of haulouts in western Hudson Bay and James Bay since the early 1900's suggest that harvesting or other human activities may be reducing these populations or causing them to move elsewhere, and that more information is required if sustainable hunts are to be assured.

14.5.7 Bearded Seal

Regulations governing the harvest and management of seals in Canada are implemented by DFO under the Marine Mammal Regulations of the *Fisheries Act*. These regulations permit Indians and Inuks to kill seals for food, or for social or ceremonial purposes without a licence. Beneficiaries of land claims agreements can also do so without a licence within the area covered by the agreement under which they are enrolled. Other residents of Hudson Bay and James Bay, which lie within Sealing Area 3, can hunt seals for food without a licence. Seals cannot be killed for sport. There are no restrictions on the sale or trade of seal pelts but a Marine Mammal Transportation Licence (export permit) is required to transport seal products across territorial/provincial boundaries.

Bearded seals are an important resource for Inuit (Smith 1981; Gamble 1984, 1987a+b, 1988; Stewart et al. 1986; JBNQNHRC 1988) and, to a lesser extent, Cree (Johnson 1961; JBNQNHRC 1982; Berkes and Freeman 1986) throughout coastal areas of Hudson and James bays. Hunting takes place mainly during the open water season but also at the floe edge or in pack ice (Figure 14-1) (Freeman 1964; Schwartz 1976). While bearded seals are harvested year-round, few are harvested between November and March when they are in the pack. Their meat is eaten or used to feed dogs and their skins are used to make tough, flexible rope and specialty items of clothing such as boot soles (Sutton and Hamilton 1932; Freeman 1967; Mansfield 1967a+b; Welland 1976; JBNQNHRC 1982; Saladin d'Anglure 1984; Stewart et al. 1986). Care must be taken in cooking the meat since it is occasionally infected with *Trichinella* sp., the parasite that causes trichinellosis (Mansfield 1967a). The liver can contain toxic levels of vitamin A.

There was interest in the late 1950's and early 1960's in increasing the availability of marine mammals, including belugas and bearded and ringed seals, to Belcher Islands Inuit--primarily as a means of ensuring against starvation and secondarily for regional economic development (McLaren and Mansfield 1960; McLaren 1962; Mansfield 1978; Freeman 1967). While the area supported a relatively large seal population the prevalence of bad weather in the open water season limited hunting. To circumvent this problem, harvesting experiments were conducted using nets. The netting was successful but there was little interest on the part of Inuit in using this technology to increase their harvests (Mansfield 1978). Subsequent decreases in the international price of seal pelts have meant that there is little commercial sealing for the species, so hunters harvest seals mostly for their own requirements (Berkes and Freeman 1986).

Few reliable harvest statistics are available for bearded seals, because they are taken for subsistence and in relatively small numbers (Cleator 1996). Data from several harvest studies in the 1980's provide a general sense of the species' importance, bearing in mind that a bearded seal can weigh 5 times more than a ringed seal (Table 14-9). A general decline in the harvest of bearded seals may have occurred since these studies were conducted (Cleator 1996), perhaps related to changes in lifestyle or in commercial demand for sealskins (Stewart et al. 1986).

14.5.8 Harbour Seal

Hunters harvest small numbers of harbour seals along the Quebec (JBNQNHRC 1988) and Nunavut coasts (Gamble 1984, 1987a+b, 1988) (Table 14-9). The relative numbers taken from coastal and fresh waters are not known. The skins of these seals are prized for making decorative boots and clothing and their meat and blubber are eaten or fed to the dogs (Freeman 1964; Mansfield 1967a; Welland 1976). In the Belcher Islands, most harbour seals are killed from a distance at their haulouts using high-powered rifles (Freeman 1964). They are very difficult to hunt in the water since they swim powerfully, are very timid, and sink immediately when killed. Before the widespread use of firearms on the Belcher Islands, they were hunted almost exclusively in summer along the Kasegalik River. Stone blinds were erected at certain rapids and the seals were ambushed as they ascended the rapids. They would also be clubbed as they came on land to by-pass a particular set of falls. Along the west coast of Hudson Bay, most harvesting takes place in summer at the heads of bays, where the water is freshest, but Inuit from Coral Harbour also hunt them at the floe edge in winter (Welland 1976).

The harbour seal's localized distribution in the Arctic makes its future somewhat precarious, since Inuit know exactly where to find it and it is an easy target when hauled out on land or swimming in a shallow stream (Mansfield 1967b; see Section 14.5.7 for sealing regulations). Some hunting occurs at the Churchill River and its estuary, and Manitoba Natural Resources has harvested seals on occasion from the area as bait for live-trapping polar bears (Remnant 1997). An active campaign to discourage harvesting of seals in the lower Churchill River was initiated in 1999 at the request of DFO (Bernhardt 2000).

14.5.9 Ringed Seal

Ringed seals are a very important natural resource for Inuit and Cree living along the coasts of Hudson Bay and James Bay (e.g., Johnson 1961; Smith 1975; Schwartz 1976; Welland 1976; Bauer 1980; Honigmann 1981; Preston 1981; JBNQNHRC 1982, 1988; Gamble 1984, 1987a+b, 1988; Saladin d'Anglure 1984; Berkes and Freeman 1986; Wein et al. 1996; McDonald et al. 1997; Cleator 2001; Reeves et al. 2001). Indeed, the site for Whale Cove was chosen because it is close to the floe edge and consequently a good area for seal hunting (Brack and McIntosh 1963). Ringed seals are harvested year-round, with most harvesting taking place from June through October (Figure 14-1) (Freeman 1964; Gamble 1988; McDonald et al. 1997; Cleator 2001). In general, the greatest subsistence harvests are taken from eastern Hudson Bay by Inuit from Sanikiluaq, Inukjuaq, and Kuujjuarapik (Table 14-9). Catches from James Bay generally are small, the largest of them coming from Chisasibi and Wemindji on the Quebec coast and Attawapiskat on the Ontario coast. This may reflect both the fact that Indians have not traditionally been hunters of sea mammals, and that seal densities may be lower and hunting conditions poorer due to the earlier breakup and later freeze-up.

The meat is eaten or used for dog food, and the skins are used to make clothing and crafts. The relatively low salinity of waters in James Bay and southeastern Hudson Bay makes seals more susceptible to sinking when they are shot, so care must be taken by the hunters to harpoon them before they are killed (McLaren and Mansfield 1960; Freeman 1964).

While ringed seals are still a vitally important resource for subsistence harvesters, the economic profit from commercial sealing has declined substantially with the advent of anti-sealing protests and the 1982 European trade embargoes. In 1980-81, immediately prior to the embargoes hunters in the Northwest Territories sold 42,120 pelts worth $890,298, while in 1983-84 they sold just 7,689 pelts worth only $76,581 (Stewart et al. 1986).

Seal meat, likely mainly ringed seal, was processed for commercial sale by the fish plant at Daly Bay and later Rankin Inlet between 1964 and 1970 (McConnell 1971; Lantz and Iredale 1972). Seal processing ended in 1970, with the discovery of high levels of mercury in marine mammal flesh and decreasing local demand for the products (Carder and Peet 1983).

Table 14-9. **Estimated mean annual subsistence harvests of seals by communities around Hudson Bay and James Bay. Sources listed below.**

Community	Period	Source	Hunters	Population[1]	ringed seals	bearded seals	harp seals	harbour seals	Seal spp.
QUEBEC									
Waskaganish	1975-6 to 1978-9	1	Cree	999					7
Eastmain	1975-6 to 1978-9	1	Cree	319					9
Wemindji	1975-6 to 1978-9	1	Cree	665					151
Chisasibi	1975-6 to 1978-9	1	Cree	1603					367
	1976-80	2	Inuit	42	14	1			
Kuujjuarapik	1975-6 to 1978-9	1	Cree	373					123
	1976-80	2	Inuit	558	1899	84	3	1	
Umiujaq	1990	3	Inuit	-[4]	762	-	-	-	-
Inukjuak	1976-80	2	Inuit	530	2081	190	7	6	
Puvirnituq	1941-72	4	inuit	-	419[5]	-	-	-	-
Akulivik	1976-80	2	Inuit	140	675	94	4	1	
Ivijivik	No data		Inuit	-	-	-	-	-	-
ONTARIO									
Moose Factory/ Moosonee	1990	5	Cree	3000					
Fort Albany	1990	5	Cree	625					
Kashechewan	1990	5	Cree	1000					
Attawapiskat	1990	5	Cree	1214					
Peawanuck	1990	5	Cree	227					
Fort Severn	1990	5	Cree	332					
MANITOBA									
Churchill[2]	May 1995-Apr. 1996	7	not stated						29
NUNAVUT[3]									
Arviat	1983-85	6	Inuit	1022	328	28	4	2	
Whale cove	1982, 1984-5	6	Inuit	188	169	14	1	3	
Rankin Inlet	1982-85	6	Inuit	1109	454	23	2	3	
Chesterfield Inlet	1983-85	6	Inuit	249	66	2			
Coral Harbour	1984-85	6	Inuit	429	748	58	49	6	
Repulse Bay	1982-85	6	Inuit	352	605	20	18		
Sanikiluaq	1980-84	8	Inuit	383	2771	125	-	3	-
TOTAL					7801	513	88	22	686

Sources: 1 = JBNQNHRC 1982, 2 = JBNQNHRC 1988, 3 = INRS-Urbanisation 1990, 4 = Smith 1975, 5 = Berkes et al. 1992, 6 = Gamble 1988, 7 = McRae and Remnant 1997; 8 = J. Pattimore, pers. comm.

[1] Populations are for the Aboriginal communities except in Nunavut, where community populations ca. 1985 are listed from the 1985 Explorers Guide. The Quebec Cree populations are 5-year means 1974-5 to 1978-79 (JBNHRC 1988); the Quebec Inuit populations are from 1976 (JBNQNHRC 1982); Ontario Cree populations are from 1990, except Attawapiskat (1989) (Berkes et al. 1995).

[2] Churchill data are reported rather than estimated harvests from 67 of 182 people identified as domestic harvesters.

[3] Nunavut means based only on years with complete harvest records.

[4] Dashes indicate no data; blank cells indicate no harvest reported.

[5] 23 years of recordsHarp Seal

14.5.10 Harp Seal

Inuit from Nunavut and Nunavik harvest small numbers of harp seals from Hudson Bay (Sergeant 1976, 1986; Gamble 1984, 1987a+b, 1988; Stewart et al. 1986; JBNQNHRC 1988). The meat is used for dog food or eaten, and the skins are used to make clothing or handicrafts or are sold to southern fur markets (Welland 1976). European embargoes have nearly eliminated commercial sales of the skins (Stewart et al. 1986).

14.6 BIRDS

Under the *Migratory Birds Convention Act, 1994*, subject to their existing rights and the regulatory and conservation regimes in the relevant treaties and agreements, Cree and Inuit may harvest migratory birds and their eggs, down, and inedible products year-round. This applies to both game birds, such as geese and ducks, and non-game birds, such as loons and guillemots. The down and inedible products may be sold but the birds and eggs can only be offered for barter, exchange, trade, or sale within or between Aboriginal communities as provided in the relevant treaties and agreements.

Migratory waterfowl comprise a significant portion of the diet of Cree and Inuit living along the coasts of Hudson Bay and James Bay (Table 14-10). They are important in particular to the Cree and to Inuit in eastern Hudson Bay, culturally, nutritionally, and economically (Hanson and Currie 1957; Freeman 1970b; Quigley and McBride 1987; Gamble 1988; Berkes et al. 1995; McDonald et al. 1997). While the subsistence harvest is essentially unregulated, Cree have a socially-enforced, traditional system for regulation of the goose hunt, comprising territories and rules which are designed to minimize disturbance of goose populations (Berkes 1982b). Waterfowl are also harvested for sport and attract non-resident hunters to tourist camps, particularly along the Manitoba and Ontario coasts of Hudson Bay, and the James Bay coast of Ontario. Seabirds, in particular thick-billed murres and black guillemots, and resident waterfowl, such as the Hudson Bay eider duck, are also important but are harvested mostly in the Belcher Islands and along the northeast coast of Hudson Bay.

The subsistence harvest of waterfowl by Cree along the Ontario coast of James Bay and Hudson Bay consists predominately of Canada geese in the spring and lesser snow geese (blue and snow geese) in the fall (Figure 14-1) (Prevett et al. 1983; Berkes et al. 1992, 1995). There is considerable variation in the annual harvests. With the exception of Kashechewan, Cree hunters largely avoid Canada geese in the fall because they develop a somewhat "fishy" taste on account of their marine feeding habits. In the spring, lesser snow geese are more readily available in northern than southern James Bay. Ontario Cree take mostly black ducks and mallards in the south, and more pintails in the north. Cree along the Quebec coast take more brant and may take a greater variety of other migratory waterfowl.

Canada geese dominate the subsistence harvest of waterfowl by Cree and Inuit along the Quebec coast and in the Belcher Islands (JBNQNHRC 1982, 1988). The majority of these geese are taken in the spring, except at Chisasibi and Kuujjuarapik, where the fall harvests are a bit larger (Figure 14-1). The harvest of lesser snow geese is smaller but still substantial. The majority of the Inuit harvest occurs in the spring, except in the Belchers where the majority of these geese are taken in the fall. Cree harvest snow geese mainly in the fall. Hunters from Wemindji and Chisasibi harvest well over half of the brant and loons taken from James Bay and Hudson Bay. The loons, mainly red-throated and common, are taken mostly in the spring and the brant in the fall. While fewer brant than other geese are harvested, the harvest is very significant in relation to the stock size and harvests by other user groups (Berkes 1982b; Berkes et al. 1992). Eiders make up the lions share of the duck harvest by Quebec Inuit, who also harvest mergansers, scoters, thick-billed murres, black guillemots, and snowy owls for food (JBNQNHRC 1988). The murres may also be vulnerable to harvest in Labrador and Newfoundland (Gaston 2002).

Table 14-10. Estimated mean annual subsistence harvests of key bird species by communities around Hudson Bay and James Bay. Sources listed below.

Community	Period	Source	Hunters	Population[1]	Canada geese	snow and blue geese	brant geese	ducks	waterfowl eggs	loons	murres	guillemots
QUEBEC												
Waskaganish	1975-6 to 1978-9	1	Cree	999	7509	9734	26	3322		25		
Eastmain	1975-6 to 1978-9	1	Cree	319	6154	1034	17	1900		81		
Wemindji	1975-6 to 1978-9	1	Cree	665	9069	1262	1892	4390		742		
Chisasibi	1975-6 to 1978-9	1	Cree	1603	29906	5683	4175	13632		1430		
	1976-80	2	Inuit	42	500	28	33	174	43	35	15	8
Kuujjuarapik	1975-6 to 1978-9	1	Cree	373	5040	2668	80	3356		426		
	1976-80	2	Inuit	558	4672	2926	478	2978	1604	440	37	79
Umiujaq	no data		Inuit	-[4]	-	-	-	-	-	-	-	-
Inukjuak	1976-80	2	Inuit	530	6603	1209	301	3988	3439	120	41	551
Puvirnituq	no data		Inuit	-	-	-	-	-	-	-	-	-
Akulivik	1976-80	2	Inuit	140	1170	453	15	800	2082	29	18	22
Ivijivik	no data		Inuit	-	-	-	-	-	-	-	-	-
ONTARIO												
Moose Factory/ Moosonee	1974-76	6	Cree	-	2639	8646	4	2837				
	1990	5	Cree	3000	11369	10973	22	6940				
Fort Albany	1974-76	6	Cree	-	3608	6378	15	2155				
	1990	5	Cree	625	3229	1006		939				
Kashechewan	1974-76	6	Cree	-	5616	7383	48	3112				
	1990	5	Cree	1000	14769	14931	228	8197				
Attawapiskat	1974-76	6	Cree	-	7275	9204	105	3187				
	1990	5	Cree	1214	16853	13750	-	-				
Peawanuck	1974-76	6	Cree	-	1921	3839	14	1004				
	1990	5	Cree	227	3932	5228		870				
Fort Severn	1974-76	6	Cree	-	1675	2637	12	338				
	1990	5	Cree	332	6210	9329	366	456				
MANITOBA												
Churchill[2]	May 1995- Apr. 96	8	not stated	-	327	249		142				
NUNAVUT												
Arviat	1983-85	7	Inuit	1022	352	409		14	641			
Whale cove	1982, 1984-5	7	Inuit	188	76	258		10	375			
Rankin Inlet	1982-85	7	Inuit	1109	481	243	11	22	175			
Chesterfield Inlet	1983-85	7	Inuit	249	55	9		4	16			
Coral Harbour	1984-85	7	Inuit	429	96	4905	5	39				
Repulse Bay	1982-85	7	Inuit	352	11	16		12				9
Sanikiluaq	no data	9	Inuit	383	2260	1091	658	6856	-	-	20	384
TOTAL (includes Ontario harvests from 1990 but not 1974-76)					130643	87392	8307	59041	8374	3328	131	1053

Sources: 1 = JBNQNHRC 1982, 2 = JBNQNHRC 1988, 3 = INRS-Urbanisation 1990, 4 = Smith 1975, 5 = Berkes et al. 1992, 6 = Prevett et al. 1983, 7 = Gamble 1988, 8 = McRae and Remnant 1997, 9 = J. Pattimore, pers. comm..

[1] Populations are for the Aboriginal communities except in Nunavut, where community populations ca. 1985 are listed from the 1985 Explorers Guide. The Quebec Cree populations are 5-year means 1974-5 to 1978-79 (JBNHRC 1988); the Quebec Inuit populations are from 1976 (JBNQNHRC 1982); Ontario Cree populations are from 1990, except Attawapiskat (1989) (Berkes et al. 1995).

[2] Churchill data are reported rather than estimated harvests from 67 of 182 people identified as domestic harvesters.

[3] Nunavut means based only on years with complete harvest records. [4] Dashes indicate no data; blank cells indicate no harvest reported.

The common eider is the most important duck to Inuit living on the coast of Hudson Bay and is particularly important to people in the Belcher Islands (JBNQNHRC 1982; Quigley and McBride 1987; McDonald et al. 1997). The species is harvested year-round for meat, skin and feathers, and nests are raided for eggs and nest down (Reed 1986). Historically the skins have been used to make fine parkas and pants, and there has been a small export of eiderdown. In the Belchers, there is ongoing interest in the commercial harvest potential of eider down (G. Gilchrist, CWS pers. comm. 2003). The species' importance is reflected in the language of Belcher Island Inuit, which has a well-developed nomenclature to describe the stages of egg and bird development (Nakashima 1988). Inuit from Sanikiluaq may eat the meat, wings, feet, gizzard, liver and heart of waterfowl (Wein et al. 1996). The meat and gizzard may be eaten cooked or raw.

Inuit in Kivalliq are far less reliant on waterfowl for food than those in Quebec (Table 14-10)(Gamble 1988; JBNQNHRC 1988). Kivalliq Inuit take Canada geese for subsistence mainly in the spring, except in the Coral Harbour where most are harvested in the fall (Gamble 1988). Most snow geese are taken in the spring, the vast majority by hunters from Coral Harbour. Few brant, Ross's geese, ducks, or guillemots are harvested but the southernmost communities do collect modest numbers of goose and duck eggs in the spring.

Non-native residents and visitors hunt geese and ducks for sport in the fall, particularly along the south coast of Hudson Bay and west coast of James Bay. There are many commercial hunting camps located along the Manitoba and Ontario coasts (OMNR 1985; Travel Manitoba 2003), and the fall harvest by their clients is substantial. In 1979 through 1983, an average of 964 hunters visited goose camps along the Ontario coast of James Bay and Hudson Bay annually, killing an overall average of 8,598 geese and 1,927 ducks annually (OMNR 1985). Non-native resident hunters of Moosonee and Moose Factory harvested over 5,000 birds, mostly snow geese, in the fall of 1982 (~13 birds/hunter). Measures to increase the sport harvest of lesser snow geese, including spring hunts and the use of special methods such as electronic call and bait, were begun in selected areas of Manitoba and Quebec in 1999 and 2000, in the spring of 2001 in Nunavut (CWS Waterfowl Committee 2004). Non–residents wishing to hunt north of the 52nd parallel in Quebec must use the services of an outfitter.

14.7 SUMMARY

Renewable resource harvesting has been, and is, a significant stressor of the Hudson Bay marine ecosystem. Its longterm effects on some populations of whales, walruses, and Arctic charr have been relatively well documented but the effects on other species and on marine habitats are poorly known.

The Nunavut Wildife Management Board (NWMB) makes all decisions relating to fish and wildlife in Nunavut, including setting quotas and non-quota limitations (e.g., fishing and hunting seasons, methods of harvest), approving management plans, and approving the designation of endangered species. Harvest restrictions or quotas that were in force on the date immediately prior to ratification of the Nuanvut Land Claims Agreement (Sec. 5.6.4), remain in effect until removed or otherwise modified by the Board. While keeping many of the established harvest quotas in the Hudson Bay marine ecosystem, this co-management board has instituted a flexible quota system for polar bear hunts by Kivalliq communities and approved community-based management of the Repulse Bay narwhal hunt, to give communities greater responsibility and flexibility in the management of their renewable resources. Ultimate approval of the NWMB decisions rests with Ministers in the governments of Nunavut and Canada who can only reject or modify a NWMB decision if it interferes with Inuit harvesting rights, creates concern with respect to species conservation, or results in a public health or safety concern. The NWMB relies on the government departments for scientific research and advice, and for regulatory support and enforcement. Its decisions are implemented under legislation by the appropriate government department.

Harvest management along the Quebec coast and its estuaries changed with signing of the James Bay and Northern Quebec Agreement (1976). Under this agreement, Inuit and Cree beneficiaries of the agreement are guaranteed certain levels of harvest, which are to be maintained unless their continuation is contrary to the principles of conservation. The Makivik Offshore Claim, which is under negotiation, will cover the coastal areas around western and northern Quebec. If approved, it may alter the management of fish and wildlife offshore the Nunavik coast in a fashion similar to the Nunavut agreement. The responsible department of the Federal or Provincial Government manages fish and wildlife hunts along the Ontario and Manitoba coasts.

Priority is given to Inuit and Cree subsistence harvesters when resources in Hudson Bay and James Bay are allocated. Where animal populations harvested by Nunavut and/or Nunavik are considered at risk of overharvesting, the total allowable harvest they can sustain and the basic needs level for native subsistence is determined. If there is a surplus in the allowable harvest it is allocated, in order of preference, to non-native residents for personal consumption, to sustain existing sport and commercial ventures, to provide for economic ventures sponsored by native organizations, and to other users.

Biota harvested from the coasts and waters of Hudson Bay and James Bay are vitally important to the Inuit and Cree. Locally, the mix of species taken and the timing of the harvests vary depending upon the animal's seasonal movement patterns, harvesting conditions, and cultural traditions. Traditionally, Inuit around Hudson Bay have harvested anadromous fishes, marine mammals, and waterfowl; some have also harvested marine plants and invertebrates. Cree along the coasts of James Bay and southern Hudson Bay harvest more migratory waterfowl but few marine mammals, and different species of anadromous fishes. Both cultures harvest some seabirds and neither has a tradition of offshore marine fishing. Most species are harvested near the coast during the open water season. But, some Arctic charr and migratory waterfowl are harvested during breakup, polar bears are harvested mostly on the winter sea ice, and seals and eider ducks are harvested year-round. Historically, marine plants and animals have provided both cultures with food, fuel, and materials to make clothing, shelter, and equipment. Today, the imputed value of these subsistence harvests on a per capita basis is substantial.

Harvesting has reduced the populations of several species in Hudson Bay. Between 1860 and 1915, American and British whalers killed an estimated 566 bowheads in northwest Hudson Bay, and nearly extirpated them from the region. Since then few bowheads have been harvested. They are considered endangered and a licence from the Minister of Fisheries and Oceans is required to hunt them. Commercial fisheries harvested a combined total of at least 8,294 belugas from Grande rivière de la Baleine and Petite rivière de la Baleine between 1852 and 1868. The eastern Hudson Bay beluga population was much reduced by these harvests and has not recovered. It is considered threatened and a quota has been placed on the subsistence harvest. Local demand for *maqtaq* has not been satisfied under these limits, so *maqtaq* has been imported from western Hudson Bay, shifting some harvesting pressure onto belugas summering in that area. Abandonment of haulouts by walruses in Hudson Bay and James Bay suggests that harvesting activities have also reduced walrus populations and/or caused them to relocate. While commercial and sport fisheries are regulated, overharvesting can occur in areas that also support large subsistence fisheries. One such area is the Diana River near Rankin Inlet, where commercial fishing has been stopped and sport and subsistence fishing reduced to facilitate population recovery.

Knowledge of the number of organisms harvested each year is limited by the quality of the harvest data, which depends upon the type of harvest (subsistence, commercial, sport), the species harvested, interest on the part of the compiler, and the community. Subsistence and sport harvest levels are not well documented for fish, bird, and seal species. These animals are killed for personal use and limits have not been placed on the subsistence harvest, so their removal is seldom monitored. This information gap seriously limits understanding of the impacts of harvesting on the Hudson Bay marine ecosystem, as most animals are harvested for subsistence. Better records are available for the larger marine mammal species that are harvested for subsistence, and occasionally for sport, and for commercial fisheries. Concern over the ability of beluga, narwhal, bowhead, polar bear, and walrus populations to support current rates of removal has resulted in regulation, and therefore monitoring, of at least some harvests of these species. There is no commercial whaling in the region and European embargoes that began in 1982 have nearly eliminated commercial sealing. Few trends in harvest patterns can be identified. A new study of subsistence harvesting in Nunavut, which may be useful for trend identification, was not available at writing.

The effects of current levels of harvest are seldom well understood, and the annual harvests vary widely. Often too little is known of the population sizes, movements, reproductive potential, natural mortality, and vulnerability to harvest in the region, and beyond, to clearly identify the impact of a particular harvest level on a population. Because sustainable harvest levels are often uncertain, managers must take an experimental approach to harvest management. Current harvest levels of eastern Hudson Bay belugas, and south and east Hudson Bay walruses may not be sustainable. Likewise, the Hudson Bay narwhal population is unlikely to support the rates of removal seen in 1999 and 2001 over the long term. In 2002, the community-based management program responded to this concern by reducing the annual harvest limit for Repulse Bay from 100 to 72 narwhals. Small groups of harbour seals are predictably available in confined areas of open water and at estuaries. This makes them very vulnerable to overharvesting. A public education program has been undertaken to reduce harvests from the Churchill River estuary. Harvests of other populations and species likely are sustainable at present, but the Southern Hudson Bay population would be over harvested if Ontario hunters took the number of polar bears to which they are "entitled". James Bay may provide a refuge for belugas and walruses, as Cree around the bay do not have a well-developed tradition of harvesting these animals. Climate change may alter the growth, survival, and reproductive potential of some, perhaps many, species and their ability to sustain harvests.

Hunt management in the region is complicated by the migrations of many of the harvested species between jurisdictions. Coastal Arctic charr quotas in western Hudson Bay, for example, specify the fishing area and can target fish from several stocks as they move along the coast. Harp and hooded seals excepted, few of the migratory marine mammals are vulnerable to harvest outside the coastal waters of Nunavut and Nuanvik. Migratory waterfowl and seabirds however, may be vulnerable to harvest from the High Arctic to the southern United States. Lesser snow goose populations, which have increased dramatically in response to changing agricultural practices in the southern United States and to effective conservation programs, present a particular challenge. Hunt managers are working to reduce their populations to an environmentally sustainable level, to avoid a population crash that would have strong adverse impacts on subsistence harvesters and likely increase harvests of other species.

Exploratory fisheries have not located shrimps, scallops, clams or marine fishes in sufficient abundance to justify the establishment of an offshore commercial fishery. The shellfish are small and slow growing relative to their southern counterparts. Few commercially attractive species of marine fishes have been located but then relatively little effort offshore fishing effort has been expended. While there is interest in the commercial harvest of kelp and green sea urchins in the Whale Cove area, the impacts of these harvests on the target species, their habitats, and other species that eat them or use the affected habitat have not been studied. Their ability to sustain harvests, and the rate of recovery of bottom habitats damaged by dragging or other methods of harvest, is unknown. The selective harvest of invertebrates in the Belcher Islands by divers is an exception, as it causes little damage to other species or habitats.

15.0 ECONOMIC DEVELOPMENT

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This section discusses economic activities, other than harvesting (see Chapter 14), that occur within the Hudson Bay marine ecosystem or in the coastal regions nearby. Despite its vast area, few people live along these coasts and very little development has occurred. Hydroelectric development is the activity with the greatest existing and potential impact on the marine ecosystem over the short and, perhaps, long term. To date there has been no offshore mineral development, and to our knowledge none is planned. There are, however, a number of new mining developments being established near the coasts. These developments have some potential to impact the marine environment through increased ship traffic, and possibly the release of contaminants. The impacts of transportation are low at present as communities are re-supplied during the openwater season and only the Port of Churchill is capable of docking and loading sea-going transport vessels. The main impacts of municipal developments on the marine environment are related to shoreline development, disturbances and the disposal of waste, all of which occur mainly in the immediate vicinity of the communities. The effects of ecotourism likely are low at present but may be increasing. The GRAND Canal Scheme, which proposes to dam the mouth of James Bay and reroute freshwater to the United States, is one development proposal that has raised serious concerns.

Sly (1994) reviewed the potential effects of development within the entire Hudson Bay watershed. Readers are referred to his work for an excellent broad overview. In the absence of complete data, workshops have been conducted to consider the potential impacts of: 1) the Grande Baleine hydroelectric development on the marine environment (Gilbert et al. 1996); 2) future hydroelectric development of the Nelson River system on belugas using the estuary (Lawrence et al. 1992); and 3) the potential cumulative impacts of regional development (Bunch and Reeves 1992; Sallenave 1994). Workshops have also been conducted to develop integrated approaches to ecosystem management (Fast et al. 2001), and to studies of ecosystem health (Cobb et al. 2001).

15.1 HYDROELECTRICITY

Hydroelectric developments have significantly altered the flow regimes of the Eastmain and La Grande rivers in Quebec, which drain into James Bay (Messier et al. 1986; Roy and Messier 1989; Hayeur 2001); the Churchill and Nelson rivers in Manitoba, which drain into southwestern Hudson Bay (Newbury et al. 1984; Rosenberg et al. 1987, 1995, 1997), and the Moose and Albany rivers in Ontario, which drain into southwestern James Bay (KGS Group et al. 1991; Stokes et al. 1999) (Table 15-1) (see also Figure 3-8). Runoff from a small portion of Grande rivière de la Baleine, which flows into southeastern Hudson Bay, has also been diverted into the La Grande system. The diversions in Quebec and Manitoba have shifted flow among rivers in the Hudson Bay watershed, changing the distribution of runoff entering the marine environment. Runoff in the La Grande River has also been augmented by the diversion of flow from the Caniapiscau River, which formerly drained via the Kokosak River into Ungava Bay, while the Nelson has been augmented by flow from headwaters of the Albany River. Large-scale impoundments have regulated flow in the Eastmain-La Grande and Churchill-Nelson systems, and altered the seasonality of their runoff into the marine environment. Runoff from the Albany River has also been diverted into the Saint Lawrence watershed via the Little Jackfish and Aguasabon rivers. The diversions of flow from the Albany have reduced its runoff into James Bay, but have not altered the seasonality of its runoff peak. Flow volume in the Moose River basin has not been altered by diversions but the seasonal runoff regime has been altered by impoundment. The longterm impacts of these water diversions on the marine environment are unknown.

Hydroelectric developments in Quebec are listed in Table 15-2 and depicted in Figure 15-1. A great deal of environmental research has been done on estuarine and marine environments related to proposed developments on Grande rivière de la Baleine, and the Nottaway and Broadback rivers, and continues for developments that have or may affect the La Grande, Eastmain and Rupert rivers.

On 18 November 1994, in response to continuing environmental concerns and a decline in the projected demand for electricity in North America, Hydro Quebec suspended plans to build the Grande Baleine hydroelectric development southeast of Hudson Bay. As proposed, this development would have involved: 1) a very large reduction in the Grande rivière de la Baleine itself and its estuary, with periodic use of the river to carry overflow;

Table 15-1. **Major drainage diversions affecting the Hudson Bay watershed (from National Atlas of Canada 5th edn 1986).**

Source basin	Receiving basin	Mean annual flow diverted ($m^3 \cdot s^{-1}$)	Total flow diverted (%)	Area (km^2)
QUEBEC				
Opinaca River (Eastmain R.), Eastmain R.	Lac Boyd (La Grande R.)	850	92	40274
Caniapiscau River (Koksoak R.)	Riviere Laforge (La Grande R. via Grande rivière de la Baleine)	790	45	38120
Grande rivière de la Baleine	Rivière Laforge (La Grande R.)	29	5	1710
MANITOBA				
Southern Indian Lake (Churchill R.)	Rat River (Burntwood R., Nelson R.)	760	70	249239
ONTARIO				
Lake St. Joseph (Albany R.)	Root River (Winnipeg R., Nelson R.)	87	90	12328
Ogoki River (Albany R.)	Little Jackfish River (L. Nipigon, L. Superior, St. Lawrence R.)	121	85	13970
Long Lake (Kenogami R., Albany R.)	Aquasabon River (L. Superior, St. Lawrence R.)	39	80	4377

2) an approximately 95% reduction in the flow of the Petite rivière de la Baleine; 3) an outflow from the system into Manitounuk Sound of about 700 $m^3 \cdot s^{-1}$ averaged over the year; 4) creation of 3,395 km^2 of reservoirs, and 5) a shift in the summer/winter freshwater outflow, very much in the favour of the winter flow (Hydro Quebec 1991c).

On 7 February 2002, under the *Boumhounan Agreement*, Hydro Quebec cancelled plans to construct the Nottaway-Broadback-Rupert (NBR) hydroelectric project. The Agreement also served to define a new project to develop the 770 MW Eastmain-1-A dam on Eastmain 1 reservoir and to divert flow--up to 586.3 $m^3 \cdot s^{-1}$ on average, from the Rupert River watershed into the Eastmain River watershed (Hydro Quebec 2002) (Figure 15-2). This diversion would increase the output of three existing generating stations on the Grande Riviere (Robert-Bourassa, La Grande-2-A and La Grande-1). Studies to assess the project's potential impacts on the environment are ongoing in preparation for submission of an Environmental Impact Statement to seek the necessary government approvals.

Construction of Quebec Hydro's 480 MW Eastmain-1 Hydroelectric Development began in the spring of 2002 (http://www.hydroquebec.com/eastmain1/en/bah/resume.html). This dam across the Eastmain River will create a 603 km^2 reservoir, with an annual drawdown of about 9 m. Its completion is scheduled for 2007.

In 1980, 80% of the flow from the Eastmain River was diverted into the La Grande River, and seasonal runoff was impounded so that it could be released to produce electricity in the winter. This has altered the seasonal freshwater plumes from the La Grande and Eastmain rivers (Peck 1976; El-Sabh and Koutitonsky 1977; Freeman et al. 1982; Ingram 1982; Messier et al. 1986, 1989; Prinsenberg 1986a; Ingram and Larouche 1987a; Roy and Messier 1989). Under these regulated conditions the natural spring freshet into James Bay does not occur at either river. The plume from the Eastmain River is much reduced and there are intrusions of saline water up to 10 km upstream, year-round (Figure 15-3; Lepage and Ingram 1986; Messier et al. 1986).

In contrast, the winter inflow of freshwater from the La Grande River into James Bay increased from 500 $m^3 \cdot s^{-1}$ under natural conditions to over 4000 $m^3 \cdot s^{-1}$ following the diversion during peak power production (Messier et al. 1986, 1989; Ingram and Larouche 1987). The area of the under-ice plume increased markedly as discharges increased to 1500 $m^3 \cdot s^{-1}$, but it showed very little change with further increases in flow since there is intense mixing at the ice edge (Figure 15-4). The plume can extend 100 km northward under the landfast ice of James Bay, and further increases in midwinter flow will lead to dilution of the nearshore surface waters in southeastern Hudson Bay (Ingram and Larouche 1987). The size and shape of the summer plume remained essentially unchanged. Its offshore limit usually coincides with the coastal shelf (0-20 m depth), despite the lower monthly mean flow and higher daily flow fluctuations following diversion (Messier et al. 1986).

Table 15-2. La Grande hydroelectric complex, 2000 (from Hayeur 2001, pg. 26).

	Reservoir level, max. (m)	Reservoir level, min. (m)	Area at max. level (km^2)	Active storage (hm^3)	Type of generating station	Number of generating units	Type of turbine	Installed capacity (MW)	Annual output (TWh)	Max. usable flow (m^3/s)	Rated net head (m)	Load factor (%)	Year of commissioning
PHASE I													
Robert-Bourassa (La Grande-2)	175.3	167.6	2,835	19,365	U	16	F	5,328	35.2	4,300	137.2	57	1979–1981
La Grande-3	256.0	243.8	2,428	25,200	S	12	F	2,304	12.3	3,260	79.2	62	1982–1984
La Grande-4	377.0	366.0	765	7,160	S	9	F	2,650	14.6	2,520	116.7	61	1984–1986
EOL (Opinaca)	215.8	211.8	1,040	3,395									1980
Caniapiscau	535.5	522.6	4,275	39,070									1984
Subtotal			**11,343**	**94,190**		**37**		**10,282**	**62.1**				
PHASE II													
La Grande-1	32.0	30.5	70	98	S	12	P	1,368	7.5	5,950	27.5	57	1994–1995
La Grande-2-A	*	*	*	*	U	6	F	1,998	2.2	1,620	138.5	57	1991–1992
Laforge-1	439.0	431.0	1,288	6,857	S	6	F	840	4.5	1,610	57.3	60	1993–1994
Laforge-2	481.1	479.6	260	390	S	2	K	310	1.8	1,200	27.4	69	1996
Brisay	**	**	**	**	S	2	K	446	2.3	130	37.5	70	1993
Subtotal			**1,618**	**7,345**		**28**		**4,962**	**18.3**				
TOTAL			**12,961**	**101,535**		**65**		**15,244**	**80.4**				

Notes: * Robert-Bourassa reservoir (formerly La Grande-2) was built during Phase I.
** Caniapiscau reservoir was built during Phase I.

Type of generating station
U Underground
S Surface

Type of turbine
F Francis
P Propeller
K Kaplan

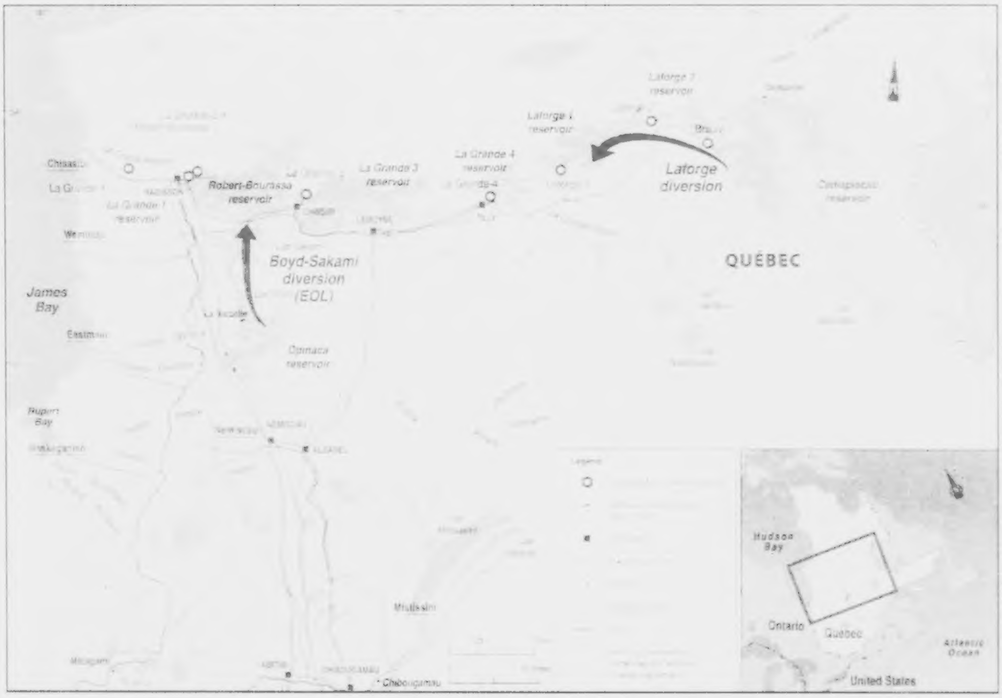

Figure 15-1. La Grande hydroelectric complex (from Hayeur 2001, pg. 27).

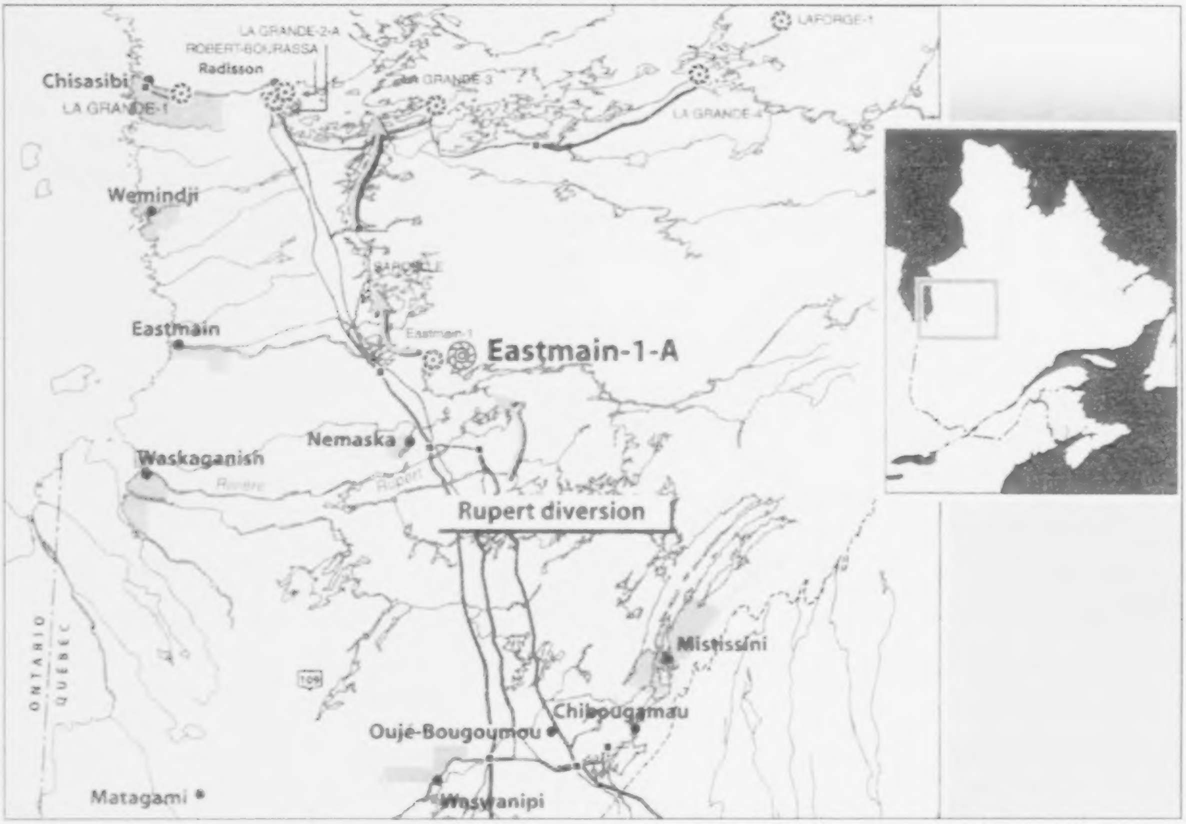

Figure 15-2. **Proposed diversion of water from the Rupert River watershed into the Eastmain watershed, and location of the proposed Eastmain-1-A hydroelectric generating station (from Hydro Quebec 2002).**

By decreasing the extent of the Eastmain plume, hydroelectric development has reduced the vertical stability of the affected coastal area (Ingram 1982; Ingram et al 1985; Lepage and Ingram 1986; Messier et al. 1986), while winter flow increases in the La Grande River have had the opposite effect (Freeman et al. 1982; Messier et al. 1986, 1989; Ingram and Larouche 1987a). Salinity and temperature distributions along the axes of the La Grande plume in March 1980, following diversion, are shown in Figure 15-5 and Figure 15-6. Over the first 5-10 km from the river mouth the freshwater outflow spreads out and slows (Freeman et al. 1982). There is thinning of the interface but no apparent increase in entrainment of salt water into the plume. For the next 25-30 km the upper water layer becomes progressively thinner as surface water is mixed, downward, by increasing sub-plume tidal action. A front-like feature with a strong horizontal density gradient separates this layer from the well-mixed area beyond where shoaling bathymetry increases tidal currents and vertical mixing of the water column seems to take place.

The biological effects of these plume changes on estuarine and marine biota are not particularly well understood (Drinkwater and Frank 1994). The reduction in freshwater flow to the Eastmain River estuary has lowered the estuarine water level, increased the tidal range and upstream intrusion of saltwater, and altered circulation (Ingram et al. 1985; Messier et al. 1986). Within the estuary, residual flow velocities are lower, currents have reversed, and tidal currents have increased. A mixed zone of fresh and salt water has developed in the lower 10 km of the river, and the estuary bottom, which was eroding under natural conditions, is now subject to sediment deposition. This deposition has resulted from bank erosion by larger tidal flows and from a

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Subtotal			11,343	94,190		37		10.282	62.1				
PHASE II													
La Grande-1	32.0	30.5	70	88	S	12	P	1,368	7.5	5,950	27.5	57	1994–1995
La Grande-2-A				*	U	6	F	1,998	2.2	1,620	138.5	52	1991–1992
Laforge-1	439.0	431.0	1,288	6,657	S	6	F	840	4.5	1,670	57.3	50	1993–1994
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Brisay		[illegible]	11	14	S	2	K	446	2.3	330	37.5	70	1993
Subtotal			1,618	7,345		28		4,962	18.3				
TOTAL			12,961	101,535		65		15,244	80.4				

[illegible]

Type of generating station
U Underground
S Surface

Type of turbine
F Francis
P Propeller
K Kaplan

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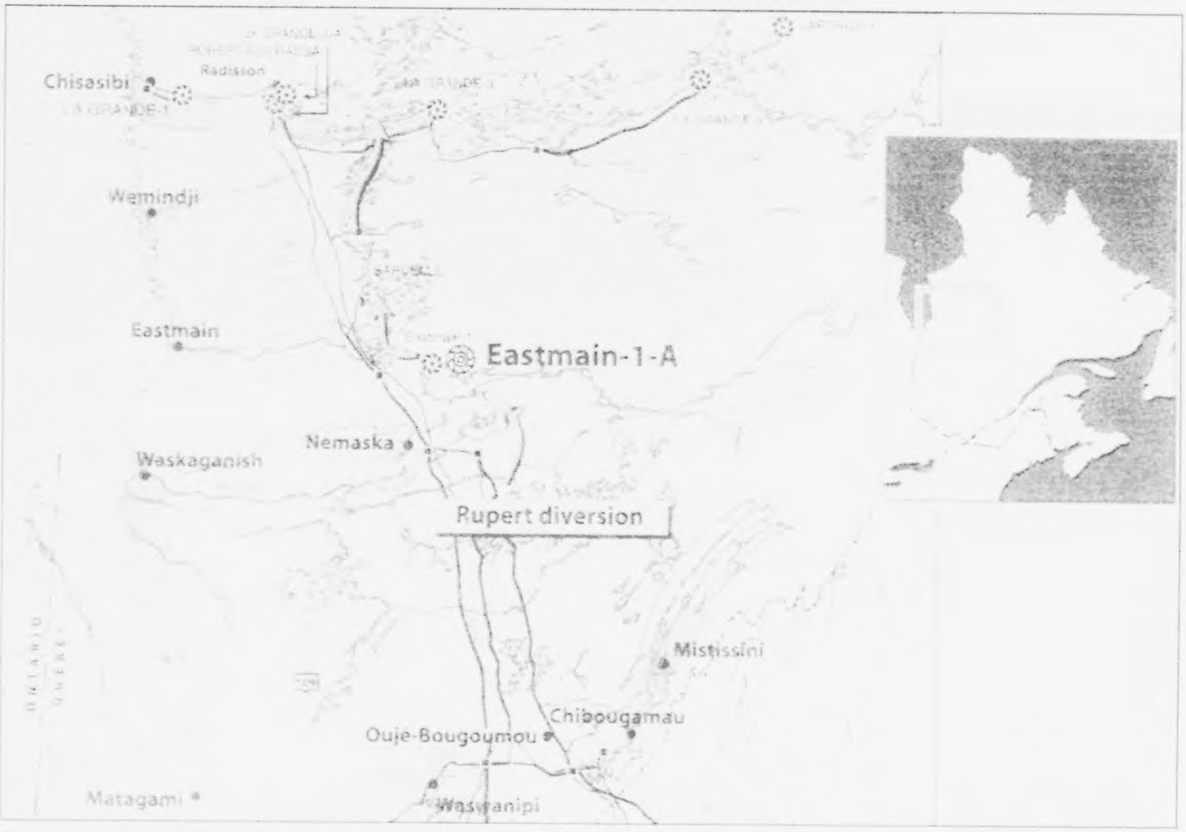

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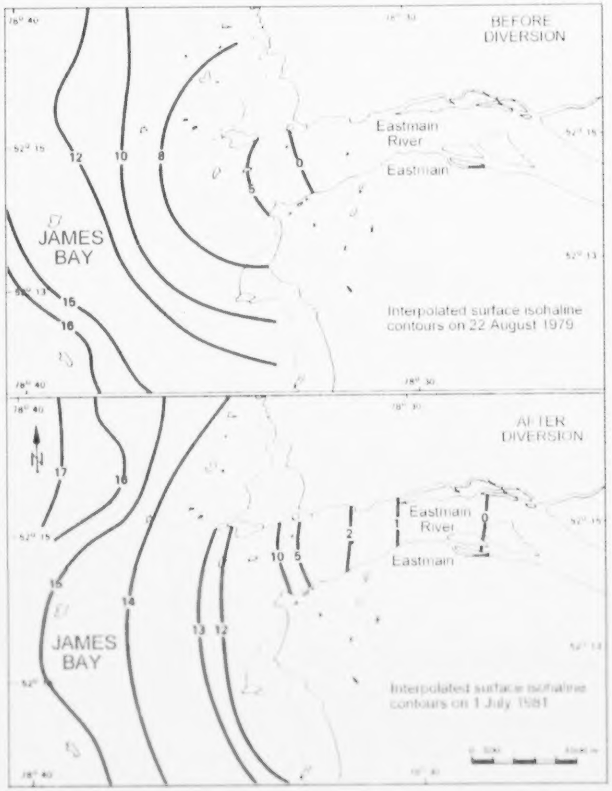

Figure 15-3. Surface isohaline contours in the Eastmain River estuary during high tide before and after Eastmain River diversion (adapted from Messier et al. 1986).

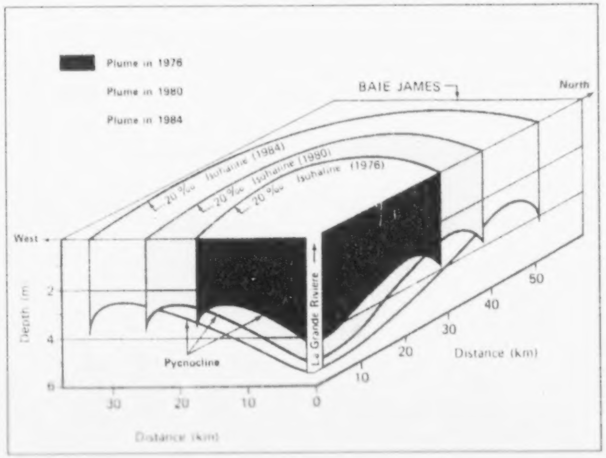

Figure 15-4. Schematic of the evolution of the La Grande River winter plume from 1976 to 1984 (from Messier et al. 1986).

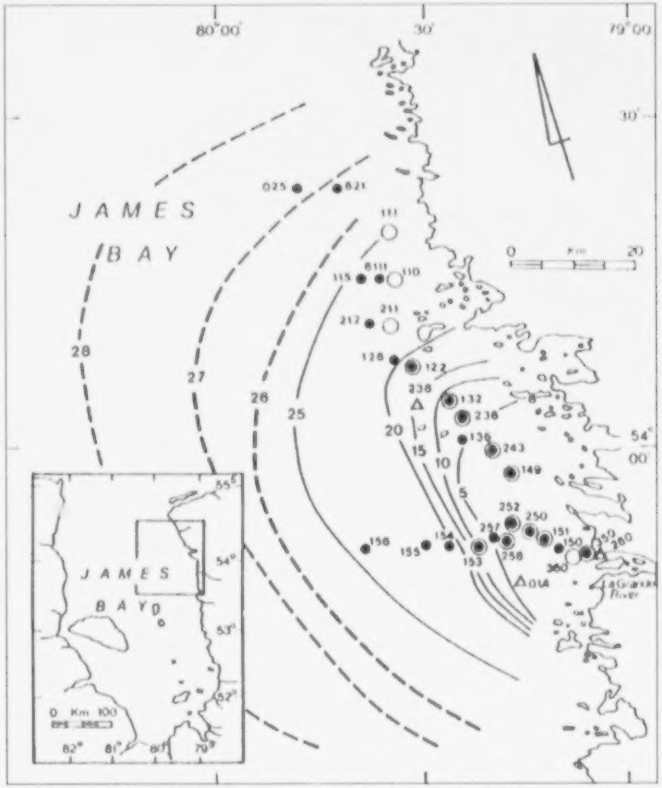

Figure 15-5. Surface salinity distribution off the La Grande River, James Bay during 15-30 March 1980. Solid dots represent conductivity-temperature-density (CTD) stations; open circles 25-hour current profile stations; and open triangles current meter stations (from Freeman et al. 1982, pg. 748).

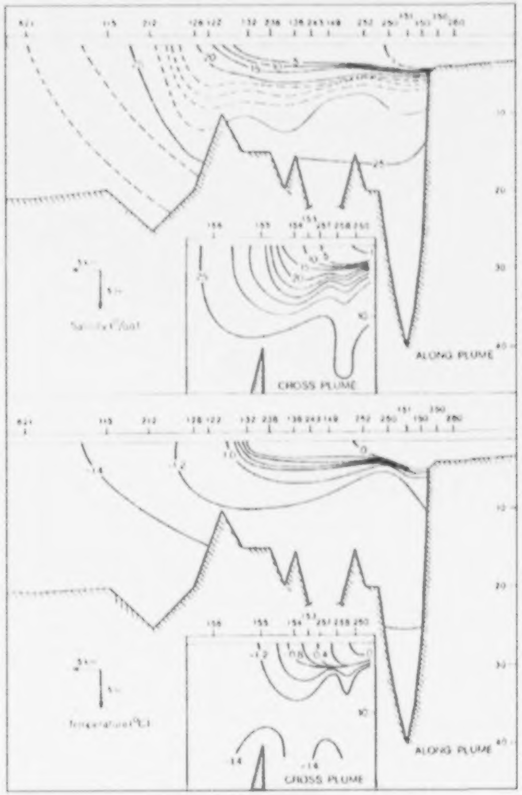

Figure 15-6. Salinity and temperature distributions along the axes of the La Grande River plume during 1-9 March 1980 (from Freeman et al. 1982, page 750). Numbers at the top of each figure refer to the sampling stations shown in Figure 15-5.

reduction in flushing by freshwater, since the sediment load carried by the river has been reduced to 3% of natural. Increased turbidity, total organic and inorganic matter, nutrients, and primary production accompanied the salinity intrusion. The source of the high nutrient concentrations is unknown, and the phytoplankton bloom was due primarily to the increased production of estuarine species (Ingram et al. 1985). There has been an upstream shift in the distribution of marine species (Ingram et al. 1985; Ochman and Dodson 1982). In contrast, the increase in flow to the La Grande River estuary has extended the influence of the freshwater plume offshore, particularly in winter (Ingram and Larouche 1987a+b). The quality of the river water remains similar, as does primary production within the river (Messier et al. 1986). Changes in fish distribution also were observed at the La Grande River estuary soon after diversion (Berkes 1982a). Post diversion monitoring has not detected significant changes in the distribution, density, or biomass of downstream eelgrass communities in response to changes in salinity (Lalumiere et al. 1994; Julien et al. 1996).

The longterm net effects of these biophysical and biochemical changes on biological productivity at all levels are unknown at either estuary. Studies in the Grande rivière de la Baleine estuary have highlighted the importance of the timing and extent of the spring freshet for the survival of larval fishes (Ponton and Fortier 1992; Ponton et al. 1993; Fortier et al. 1995, 1996) (see also Section 8.3). How changes in the Eastmain and La Grande plumes have affected prey density, and availability and thereby larval survival, is unknown but could be important. The effects of estuarine changes related to hydroelectric development on marine mammals and birds are unknown.

Mercury levels in the La Grande system rose considerably following diversion but are now declining (Schetagne and Verdon 1999; Hayeur 2001). Elevated mercury levels have been found in the flesh of marine fishes within 10-15 km of the river mouth. The expected time before mercury concentrations fall back to the condition before the start of operations is about thirty years overall. Mercury was not elevated in fish sampled at the Nelson River estuary in 1989 (Baker 1990) but there is little or no data since then, or from the Moose River estuary. Elevated levels might occur in future if waters closer to these estuaries are impounded. Dams on the lower reaches of rivers are also more likely to alter seasonal movements of anadromous fishes between freshwater spawning and overwintering habitats and estuarine feeding habitats. They might also limit upstream movements by bearded and harbour seals.

Modelling of the potential effects of hydroelectric development on oceanographic surface properties by Prinsenberg (1983) suggests that changes in the runoff cycle caused by hydroelectric development may affect the timing of the formation of a new pycnocline in the spring, and its subsequent depth and stability in Hudson Bay. Prinsenberg (1982a) also predicted that the vertical salinity gradients and currents in James Bay would increase in winter, affecting circulation of water in the bay (Figure 15-7). Modelling by Prinsenberg and Danard (1985) suggests that the surface temperature is buffered somewhat against man-made changes. They predicted that a decrease in surface temperature such as might be caused by hydroelectric development of surrounding watersheds would be gradually offset by the stabilizing effects of the colder water on the overlying air. This would act to decrease wind stress and increase the heat flux into the water. The reverse should be true in the case of an increase in water temperature. However, existing seasonal data are insufficient to test the models and facilitate predictions of the magnitude of any changes.

Ice-ocean modelling studies suggest that the bay-wide effects of the power plants are small compared with the natural variablility observed in the ice cover (Saucier and Dionne 1998). The effects of replacing the natural runoff cycle with that regulated by planned hydroelectric developments were examined using data from Prinsenberg (1980). Under this scenario, 50 km^3 more fresh water would enter the bay between January and April than under natural conditions. The results suggest that about 10% of this additional water may form ice, increasing ice thickness in southeastern Hudson Bay by about 10 cm; the rest would remain liquid. The thicker ice could delay breakup in southeastern Hudson Bay by 2-3 days but the additional fresh water may also enhance water column stability. The summer surface salinity would decrease by -0.1 ppt (≈psu) on average over the bay

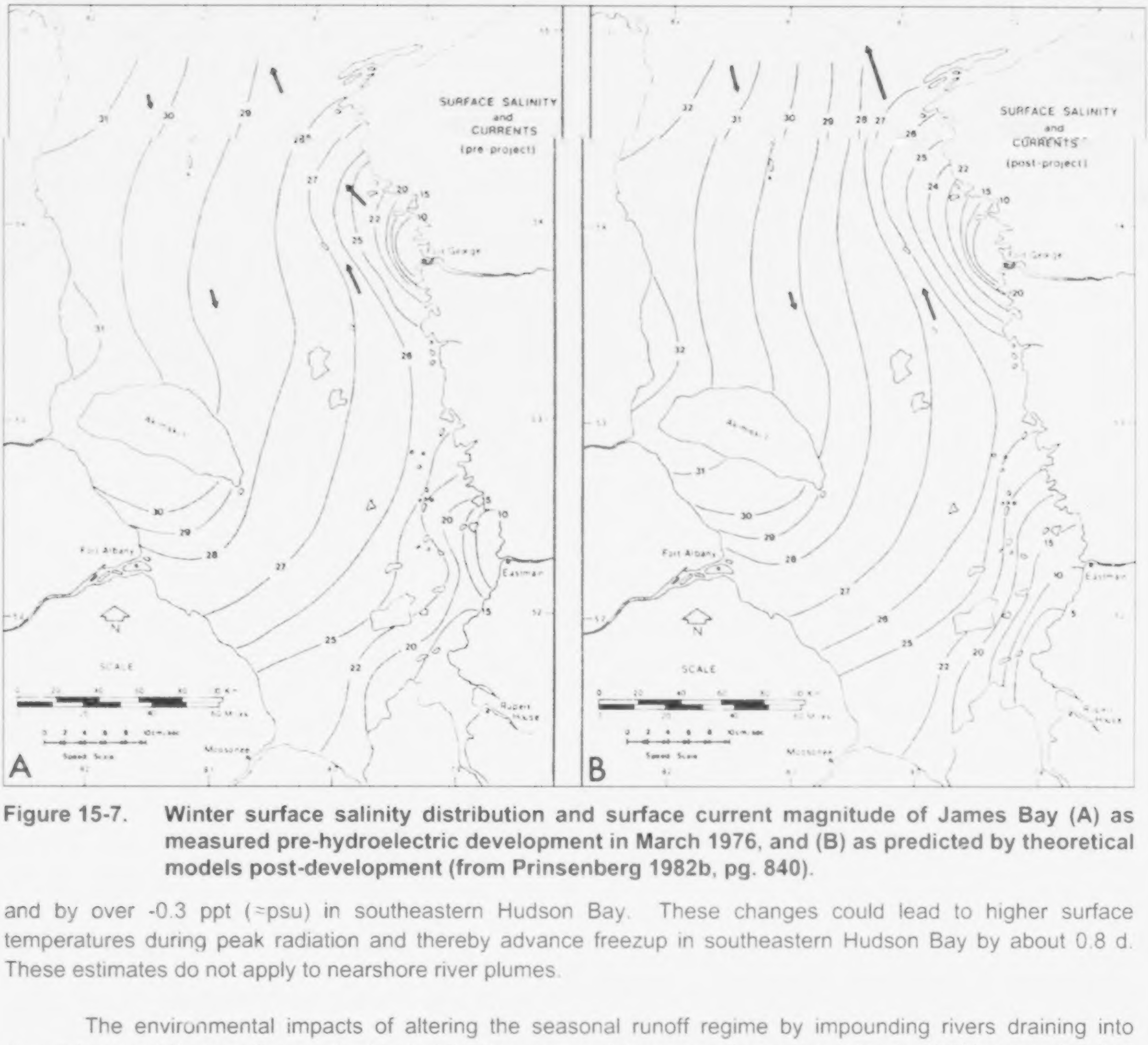
SURFACE SALINITY and CURRENTS (pre-project)
SURFACE SALINITY and CURRENTS (post-project)
Fort George
Akimiski
Fort Albany
Eastmain
Rupert House
Moosonee
N
SCALE
Speed Scale
A
B

Figure 15-7. **Winter surface salinity distribution and surface current magnitude of James Bay (A) as measured pre-hydroelectric development in March 1976, and (B) as predicted by theoretical models post-development (from Prinsenberg 1982b, pg. 840).**

and by over -0.3 ppt (≈psu) in southeastern Hudson Bay. These changes could lead to higher surface temperatures during peak radiation and thereby advance freezup in southeastern Hudson Bay by about 0.8 d. These estimates do not apply to nearshore river plumes.

The environmental impacts of altering the seasonal runoff regime by impounding rivers draining into James Bay and Hudson Bay on the North Atlantic are uncertain and controversial. Mysak (1993) suggested that they might be far-reaching and that, "*cumulative hydroelectric development around Hudson Bay…could lead to a reduction in the rate of overturning in the Labrador Sea…thus weakening the global thermohaline circulation…resulting in a cooler climate in Europe and eastern North America.*" LeBlond et al. (1996) argued that the hydro-related changes in runoff would be insignificant on this large scale relative to the natural variability, and undetectable. They did not address the question of whether the shift in the range of natural variability might have an effect over the longterm.

In Ontario, there are sixteen hydroelectric generating stations in the Moose River basin that affect James Bay and Hudson Bay Figure 15-3, Figure 15-8). Within the basin, there is considerable potential for the redevelopment and extensions of existing sites, and for the development of new sites on the Moose, Mattagami and Abitibi rivers (KGS Group et al. 1991). Future hydroelectric development of the Missinaibi River, another tributary of the Moose, has been effectively precluded by its designation as a provincial waterway park and nomination as a Canadian Heritage River (http://www.chrs.ca). Ontario Power Generation Inc. has environmental approval to construct the Mattagami River Generating Station Extensions, which consist of additions of one unit to

Table 15-3. Generating capacity of hydroelectric stations in the Moose River Basin (Nyboer and Pape-Salmon 2003).

Generating Station	Capacity (kW)	Operator	In service date
2. Mattagami Complex			
Little Long	[illegible]	Ontario Power Generation Inc.	[illegible]
Smoky Falls	[illegible]	Ontario Power Generation Inc.	[illegible]
Harmon	[illegible]	Ontario Power Generation Inc.	[illegible]
Kipling	[illegible]	Ontario Power Generation Inc.	[illegible]
3. Kapuskasing Hydro	[illegible]	[illegible]	[illegible]
4. Carmichael Falls	[illegible]	[illegible]	[illegible]
9. Smooth Rock Falls	[illegible]	Tembec	[illegible]
10. Lower Sturgeon	[illegible]	Ontario Power Generation Inc.	[illegible]
11. Sandy Falls	[illegible]	Ontario Power Generation Inc.	[illegible]
12. Wawaitin	[illegible]	Ontario Power Generation Inc.	[illegible]
14. Otter Rapids	182400	Ontario Power Generation Inc.	1961
15. Abitibi Canyon	[illegible]	Ontario Power Generation Inc.	[illegible]
16. Island Falls	[illegible]	Abitibi Consolidated Inc.	[illegible]
18. Long Sault Rapids	[illegible]	[illegible]	[illegible]
19. Iroquois Falls	[illegible]	Abitibi Consolidated Inc.	[illegible]
20. Twin Falls	[illegible]	Abitibi Consolidated Inc.	[illegible]

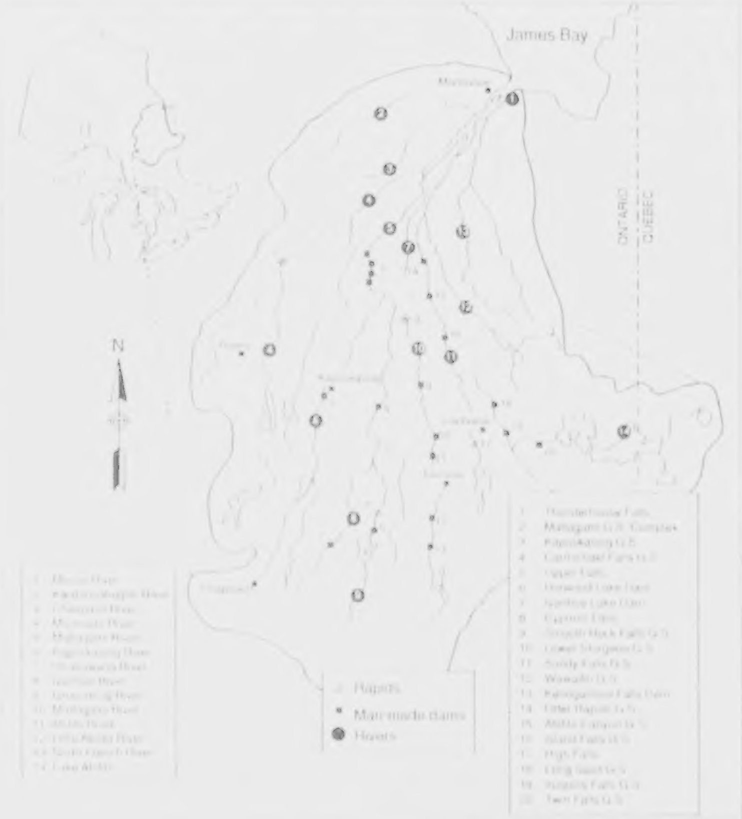

Figure 15-8. Existing hydroelectric dam locations in the Moose River Basin (adapted from Stokes et al. 1999, pg. 2).

Table 15-3. Generating capacity of hydroelectric stations in the Moose River Basin (Nyboer and Pape-Salmon 2003).

Generating Station	Capacity (kW)	Operator	In service date
2. Mattagami Complex:			
Little Long	133000	Ontario Power Generation Inc.	1963
Smoky Falls	52280	Ontario Power Generation Inc	1928
Harmon	140800	Ontario Power Generation Inc	1965
Kipling	141460	Ontario Power Generation Inc	1966
3. Kapuskasing Hydro	2750	Spruce Falls Inc.	1923
4. Carmichael Falls	18000	Algonquin Power Corp. Inc.	1995
9. Smooth Rock Falls	8000	Tembec	1917
10. Lower Sturgeon	5360	Ontario Power Generation Inc.	1923
11. Sandy Falls	3200	Ontario Power Generation Inc.	1911
12. Wawaitin	10630	Ontario Power Generation Inc.	1912
14. Otter Rapids	182400	Ontario Power Generation Inc.	1961
15. Abitibi Canyon	310000	Ontario Power Generation Inc.	1933
16. Island Falls	44000	Abitibi-Consolidated Inc.	1921
18. Long Sault Rapids	18000	Algonquin Power Income Fund	1998
19. Iroquois Falls	19085	Abitibi-Consolidated Inc.	1949
20. Twin Falls	24750	Abitibi-Consolidated Inc.	1921

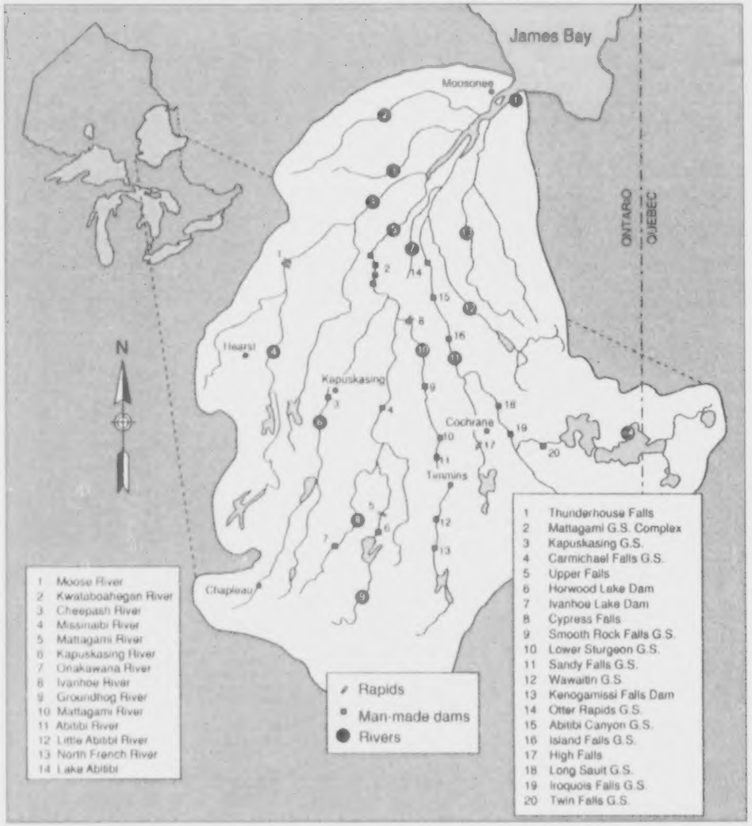

Figure 15-8. Existing hydroelectric dam locations in the Moose River Basin (adapted from Stokes et al. 1999, pg. 2).

the Little Long (62 MW), Harmon (68 MW), and Kipling (68 MW) generating stations and the construction of a new powerhouse (3 x 80 MW) adjacent to the existing Smoky Fall Generating Station (KGS Group et al. 1991). To date, project construction has not commenced despite local support (Town of Moosonee Regular Meeting Minutes August 17, 2004, Resolution 04-310).

Flow in the Moose River watershed is regulated. However, the impoundments created by the dams are small relative to those in Quebec and Manitoba, so the effect on the seasonal flow regime of runoff into James Bay should be small. Of the four stations closest to James Bay only Little Long, the uppermost, has a significant forebay (71.67 km^2) (KCG Group et al. 1991). The proposed extensions to the existing generating stations should have little effect on the existing hydrology and flows. No marine studies related to hydroelectric development of the Moose River basin were located.

Hydroelectric developments in Manitoba that affect Hudson Bay and James Bay are listed in Table 15-4 and depicted in Figure 15-9. In 1976, 75% of the flow of from the Churchill River was diverted into the Nelson River to produce hydroelectric power (Prinsenberg 1980; Newbury et al. 1984; see also Rosenberg et al. 1987, 1995, 1997). This has reduced runoff from the former while increasing it in the latter. Unfortunately, the estuarine impacts of this change cannot be determined, as neither estuary was studied prior to diversion. Changes in the Churchill Estuary may resemble somewhat those in the Eastmain River estuary, where flows were also reduced, while changes in the Nelson River Estuary may resemble somewhat those in the La Grande River estuary, where flows were augmented. Post-diversion studies of the Nelson River estuary have been ongoing since 1988, to obtain data prior to construction of further generating stations on the lower Nelson River, in particular the Conawapa Generating Station (e.g., Baker 1989, 1990; Baker et al. 1993, 1994; Horne 1997; Horne and Bretecher 1998; Zrum

Table 15-4. **Generating capacity of hydroelectric stations on the Nelson River, Manitoba (Nyboer and Pape-Salmon 2003).**

Generating Station	Capacity (kW)	In service date
Kelsey	236250	1960
Kettle	1224000	1970
Jenpeg	168000	1977
Long Spruce	977500	1977
Limestone	1330000	1990

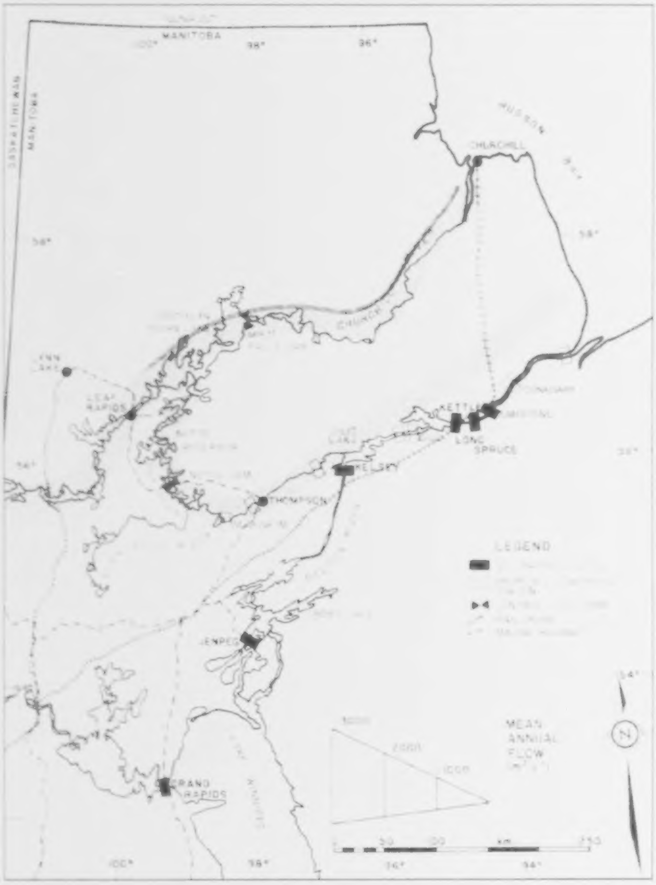

Figure 15-9. **Churchill and Nelson rivers hydroelectric development, indicating the altered flow regime of the rivers. Dark tone indicates relative magnitude of lower Churchill River discharge remaining after diversion; mid-tone indicates portion of Churchill River discharge diverted at Southern Indian lake; light tone indicates Nelson River discharge (adapted from Newbury et al. 1984, pg. 550).**

1999, 2000). The lower Churchill River and its estuary have also been studied since 1993, to assess the impacts of constructing a rock weir across the river to mitigate problems caused by low flow (e.g., Baker et al. 1994; Lawrence and Baker 1995; Peake and Remnant 2000). The weir was constructed in 1999. It has impounded the lower Churchill River to raise the water level, with the goal of improving boat access and fish habitat.

Manitoba Hydro is considering further developments on the Nelson River system. At writing, these considerations are most advanced for the 200 MW Wuskwatim Project, a "run-of-the-river" facility on the Burntwood River that would cause little flooding and rely on seasonal flow to produce power. The Manitoba Clean Environment Commission (MCEC) has conducted public environmental hearings for the project, and submitted its recommendations to the Manitoba Conservation Minister for consideration in early October 2004 (MCEC 2004). Manitoba Hydro is also considering the construction of two projects on the Nelson River, the 600 MW Gull (Keeyask) Generating Station about 30 km west of Gillam, and the 1380 MW Conawapa Generating Station on the lower Nelson River, about 28 km downstream of the Limestone Generating Station (http://www.manitobaenergy.ca). Environmental impact studies are ongoing for both projects. A Joint Federal-Provincial Environmental Impact Review was initiated for Conawapa in 1991-2. It was cancelled shortly after the draft guidelines for the EIS were submitted (see Conawapa Environmental Review Panel 1992), when Ontario decided not to enter into a long-term agreement to purchase power generated by the facility.

The Kivalliq coasts and Richmond Gulf in northern Quebec, also known as Lac Guillaume-Delisle, are the coastal areas least affected by hydroelectric developments. There are no hydroelectric developments in the Kivalliq, which is upstream of other developments that affect Hudson Bay and James Bay. The inflow to Richmond Gulf is from Clearwater Lake, which is unaffected by hydroelectric development plans, and the outlet to the sea, in the southwest, is narrow and shallow. It does not receive water from southeastern Hudson Bay, and is therefore not affected by the coastal circulation.

15.2 MINERALS AND HYDROCARBONS

There are no offshore mineral or hydrocarbon developments in Hudson Bay or James Bay. There has been some offshore mineral exploration and oil drilling in southwestern Hudson Bay, in the Hudson Platform, but to our knowledge no oil or gas discovery has been made, and no exploration is ongoing (Table 15-5, Figure 15-10). There are oil reserves, estimated at 190 billion barrels (Nelson 1981), in the petroliferous Ordovician shales that outcrop on Southampton Island but their extraction has not been economically attractive (see Section 3.1).

The only coastal mine, for nickel at Rankin Inlet, has been closed since the 1960s. The mine property is now owned by Comaplex Minerals Corporation, which is exploring for base metals beneath the southeast edges of the community (http://www.comaplex.com/pages/other_properties.html).

Precambrian terrains bordering the Hudson Platform may hold important mineral deposits (Johnson et al. 1986). They have the potential for discovery and development of base and precious metals, diamonds, asbestos,

Table 15-5. Hydrocarbon wells in Hudson Bay, see Figure 15-10 for locations (from http://www.margin.gsca.nrcan.gc.ca/metamap/margin.mfw).

Site	Company	Wellsite	Coordinates	Drill Ship
1	Trillium Soquip Onexco et al	Beluga O-23; depth range 1580-2210 m	59°20'N, 88°30'W	Neddrill II
2	ICG Sogepet et al	Netsiq N-01	60°00'N, 87°30'W	Neddrill II
3	Aquitaine et al	Walrus A-71	58°40'N, 87°00'W	Wodeco II
4	Aquitaine et al	Polar Bear C-11	58°40'N, 86°45'W	Pentagone 82
5	Aquitaine et al	Narwhal South O-58	58°10'N, 84°00'W	Pentagone 82

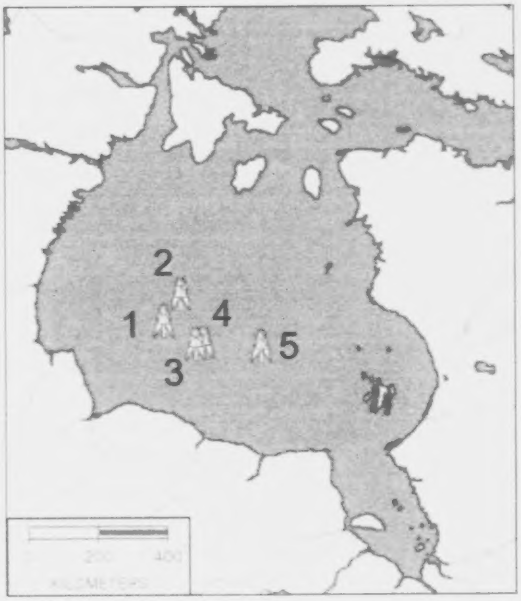

Figure 15-10. Petroleum exploration wells, see Table 15-5 for data (from http://www.margin.gsca.nrcan.gc.ca/metamap/margin.mfw).

phosphate, gypsum, limestone, aggregate, and perhaps other minerals and materials (Johnson et al. 1986; NMRS 2001; Houle 2003, 2004; Moukhsil 2003; Perrault and Moorhead 2003; CIWGMI 2003; Perrault 2004).

In the Kivalliq Region of Nunavut, at least eight inland exploration projects were ongoing in 2003 (Table 15-6). Rankin Inlet, Arviat, and Baker Lake are the main staging points for these projects, which have been exploring for gold, base metals, and diamonds. Extensive surface exploration for uranium has been conducted west of Baker Lake over the past several decades, but no mine development is planned at present. In 1997, CAMECO Resources Inc. suspended its' field exploration program for uranium, citing lack of access to Inuit-owned land as one reason for its decision (Wilkin 1999). In 2002, the Canadian Nuclear Safety Commission revoked the project's Mining Facility Removal Licence at the company's request (CNSC 2002). While surface exploration activities can continue, uranium mine development cannot proceed until a new licence is issued.

Mineral exploration projects conducted in 2002 and 2003, within 150 km inland from the Quebec coast of Hudson Bay and James Bay, are summarized in Table 15-7 and Table 15-8. Those east of Hudson Bay were situated along the coast of the Hudson Bay Arc--the East Hudson Tan Project excepted. They were exploring primarily for gold and base metals (Perrault and Moorhead 2003; Perrault 2004). Projects east of James Bay were located further inland, either south of Rupert Bay or east of Eastmain and Wemindji. They were exploring primarily for diamonds associated with kimberlite deposits, and for precious and base metals (Houle 2003, 2004). While diamond-bearing kimberlite and some high-grade metal deposits have been identified, none of these projects is sufficiently advanced to provide a good estimate of the target resource.

The same is true inland from the Ontario and Manitoba coasts. In Ontario, De Beers Canada is conducting a feasibility study of diamond-bearing kimberlite deposits on its Victor Project, 90 km west of Attawapiskat, and sampling three other nearby kimberlites (http://www.debeerscanada.com/). MacDonald Mines Limited is exploring for diamonds and precious metals further inland (http://www.macdonaldmines.com/). In Manitoba, there is diamond exploration in the northern Superior Province and on the Hudson Bay Lowland (http://www.gov.mb.ca/itm/mrd/busdev/exp-dev/index.html).

Mineral deposits in the Kivalliq Region may be developed over the next decade. While they are situated inland, any development likely will require expediting services provided by the communities, improved port facilities, and servicing by shipping on Hudson Bay. Development potential along the Quebec coast of Hudson Bay, where exploration is at an earlier stage, is less certain. If development occurs along the Hudson Bay Arc, it too may rely on the coastal communities and Hudson Bay shipping for logistical support. Mining developments inland from the James Bay and southern Hudson Bay coasts may be less reliant on the coastal communities, provided that supplies, materials, and products can be transported to and from the south by road or rail.

Table 15-6. **Mineral exploration projects conducted west of Hudson Bay in the Kivalliq Region of Nunavut during 2003 (CIWGMI 2004; see also websites listed below)**

PROJECT	LOCATION	COMMODITIES*	OPERATOR	WORK or INFERRED RESOURCE
Churchill Diamond and	extends from 15 km NW of Rankin Inlet towards Chesterfield Inlet NTS 55J, 55N, 55O	Diamonds	Shear Minerals Ltd., Stornoway Diamond Corp., BHP Billiton.	Prospecting, till sampling, aeromagnetic and ground geophysical surveys, 16 kimberlites located. http://www.shearminerals.com
Churchill West Diamond	NTS 55N	Diamonds	Shear Minerals Ltd., Stornoway Diamond Corp., BHP Billiton.	Prospecting, till sampling, aeromagnetic and ground geophysical surveys, 2 kimberlites located. [illegible]
Ferguson Lake	230 km W of Rankin Inlet NTS 65I/14,15 (96°51'N, 62°52'W)	Ni, Cu, Co, Pd, Pt	Starfield Resources	1.2 billion lbs Cu, 713 million lbs Ni, 80 million lbs Co, 2.4 million oz. Pd, 0.4 million oz. Pt. [illegible]
Fox	100 km NW of Rankin Inlet NTS 55N/06 (93°20'N, 63°16'W)	Au, Ag	Comaplex Minerals	Prospecting, sampling, mapping; currently looking for another partner. [illegible]
Meadowbank (Vault Zone)	75 km N of Baker Lake NTS 66H/01; 56E/04 (96°00'N, 65°04W)	Au	Cumberland Resources	Estimated 3.5 million oz. Au, additional drilling, Environmental assessment process initiated. [illegible]
Meliadine East	20 km NE of Rankin Inlet 56J	Au; Diamonds	Cumberland Resources; Comaplex Minerals	Till sampling, drilling; 0.3 million oz. Au. [illegible]
Meliadine West	30 km N of Rankin Inlet NTS 55J/13; 55K/16; 55N/01 (92°11'N, 63°01'W)	Au	Cumberland Resources; Comaplex Minerals	22.1 million tonnes grading 8.5 g/t Au. [illegible] (NMRS 2001)
Qilalugaq	near Repulse Bay	Diamonds	BHP-Billiton	Till sampling, drilling, airborne surves, mini bulk sampling of kimberlite pipes. [illegible]

Au = gold, Ag = silver, Cu = copper, Co = cobalt, Ni = nickel, Pb = lead, Pd = palladium, Pt = platinum.

See also: [illegible]
[illegible]
[illegible]
[illegible]
[illegible]

Table 15-7. **Mineral exploration projects conducted within 150 km inland from the Quebec coast of Hudson Bay in the northern Superior Province in 2002 (Perrault and Moorhead 2003) and 2003 (Perrault 2004).**

PROJECT	LOCATION	COMMODITIES*	OPERATOR	WORK
East Hudson	NTS 33K,L,M,N,O; 34B,C,F,G,H,J,K,L	Ni, Cu, Co, PGE	Falconbridge Ltd., and SOQUEM Inc.	2002+3: geological mapping, prospecting, sampling, geochemical surveys.
East Hudson Tan	NTS 34B,C,F,G	Ni, Cu, Co, PGE	Falconbridge Ltd., and SOQUEM Inc.	2003: prospecting, sampling, geochemical and electromagnetic surveys.
Inukjuak	NTS 34L/09	Au, Cu, Pb, Zn	Fonds minier du Nunavik	2002: prospecting
Bates Peninsula	NTS 34L/09	Au, Cu, Pb, Zn	Jacob Palliser	2002: prospecting
Kuujjuarapik 1	NTS 33N/05	Au, Pb, Zn.	Moses Weetaltuk, Myua Niviaxie	2003: prospecting
Kuujuarapik 2	NTS 33N/11	Pb, Zn	Nunavik Mineral Exploartion Fund	2003: prospecting
Fivemile Inlet	NTS 34L/09	Au, Cu, Pb, Zn	Peter Tukai	2002: prospecting
Umiujuaq	NTS 34L/09	Cu, Pb, Zn	Nunavik Mineral Exploration Fund; SOQUEM Inc	2002+2003: prospecting
Sheldrake River	NTS 34L/09	Cu, Pb	Adamie Tooktoo	2002: prospecting
Black Whale	NTS 23N/05	Pb, Zn	Myva Niviaxie	2002: prospecting

* Au = gold, Ag = silver, Cu = copper, Co = cobalt, Ni = nickel, Pb = lead, PGE = platinum group elements, Zn = zinc.

Table 15-8. **Mineral exploration projects conducted within 150 km inland from the Quebec coast of James Bay in 2002 (Houle 2003) and 2003 (Houle 2004).**

PROJECT	LOCATION	COMMODITIES*	OPERATOR	WORK
Hernia	NTS 32L, M	Diamonds	Dumont Nickel	2002: drilling
Nottaway Central	NTS 32M/01,02	Diamonds	Poplar Resources	2002: lake bottom geochemical survey
Nottaway Nord	NTS 32L/09,10,15,16; 32M/01,02	Diamonds	Majescor Resources	2002+2003: lake bottom geochemical survey, magnetic surveys, drilling.
Clearwater	NTS 33B/04	Au	Eastmain Resources	2003: drilling and trenching
EM Baie	NTS 33B/03, 32N/07, 33F/08, 33P/03, 33F/06, 32N/02, 32N/07, 33C/03	Ag, Au, Cu, Zn, Diamonds	SOQUEM and Inco	2003: prospecting, drilling, electromagnetic surveys
Eastmain-1	NTS 33C/01	Au, Cu	Les Explorations Carat	2003: trenching and stripping
Eleonore	NTS 33C/09	Au, Cu	Virginia Gold MInes	2003: sampling, prospecting, trenching and stripping
Wemindji	NTS 33C/13	Diamonds	A. Grigorita	2003: prospecting and geochemical surveys
James Bay	NTS 33F,G	Diamonds	Dianor Resources	2003: sampling, prospecting, geological mapping, drilling, geochemical and magnetic surveys
Five Diamonds	NTS 33F/04	Diamonds	Antoro Resources Inc.	2003: Geochemical and magnetic surveys.
Wemindji	NTS 33D/15	Diamonds	Orezone Resources and Patrician Diamonds	2002: lake bottom geochemical survey
Wemindji	30 km E of Wemindji NTS 33D/15,16; 33E/01,02	Diamonds	Majescore Resources	2002: sampling, gochemical and electromagnetic surveys, drilling
Sakami	NTS 33F/02, 33F/07	Au	Matamec Explorations	2002+2003: prospecting, geological and induced polarization surveys, drilling, trenching and stipping
Wapiscan – Riviere des peupliers	NTS 33F/03,04	Diamonds, Cu, Au, Ag	AntOro Resources	2002+2003: prospecting, sampling, geochemical magnetic and electromagnetic surveys
Ménarik	NTS 33F/06	Cu, Cr, Ni, Pd, Pt	Pro-or Mining Resources	2002+2003: sampling, magnetic and electromagnetic surveys, metallurgical testing.
Yasinski-North	NTS 33F/05,06	Diamonds, Au, Cu, Ni, Zn	Searchgold Resources	2002: prospecting, geochemical surveys
Blue Jay	NTS 33F/06	Diamonds	Paul Adomatis	2002: prospecting, till goechemical survey
Whisky Jack	NTS 33F/06	Diamonds	Gordon Henriksen	2002: prospecting, till goechemical survey
Radisson	NTS 33F/06	Diamonds, Cu, Zn, Au	Guy Galarneau	2002: prospecting, sampling
James Bay	NTS 33D-F	Diamonds	Dianor Resources	2002: prospecting; geological, Geochemical, magnetic and airborne geophysical surveys
La Grande sud	NTS 33F/07,09,10	Au	Virginia Gold Mines and Cambior	2002: electromagnetic survey, drilling

* Au = gold, Ag = silver, Cu = copper, Co = cobalt, Ni = nickel, Pb = lead, Pd = palladium, Pt = platinum, Zn = zinc

15.3 TRANSPORTATION

Hudson Bay's proximity to European markets was well recognized by fur traders and whalers, but it was not until the grain-producing capabilities of the Canadian prairies became apparent that a Hudson Bay shipping route was envisaged. Following completion of the railway link with western Canada, the route became a reality in 1931, when the first freighters loaded with Canadian wheat cleared Churchill Harbour (Jones 1968). Today, annual vessel traffic within Hudson Bay includes freighters that visit the Port of Churchill to load prairie grain; ships or coastal barges that re-supply the other communities with food, dry goods, and fuel (sealift); and occasional luxury liners. Hudson Bay is a major access route to Nunavut, with the Port of Churchill and the Port of Montreal serving as the major gateways. Despite regular ship traffic to and from the region since the 1600's, few natural alterations are apparent apart from the Port of Churchill, smaller docking facilities elsewhere, and a few marine hulks. Vessel traffic is largely confined to the open water season so there is seldom a requirement for ice-breaking.

The modern shipping season is determined to a great extent by insurance rates, which increase early and late in the season (Jones 1968). The best rates are based on entry into Hudson Strait after 0001 h on 23 July and departure from Churchill by 15 October. On average the first deep-sea vessel arrives at Churchill on 27 July and the last one leaves on 11 October. Coastal vessels that winter at Churchill often start their season in early to mid-July, depending on ice conditions, and work along the coast between the shore and the pack ice (B. Pappas, Moosonee Transport Limited, Moosonee, per. comm.; L. Robb, Port of Churchill, Churchill, pers. comm.). Only vessels drawing less than 3.9 m (13 ft) can pass through Chesterfield Inlet and enter Baker Lake.

The volume of grain shipped from Churchill varies widely: 711,000 metric tones (mt) in 2000; 478,000 mt in 2001; 279,000 mt in 2002, when prairie grain production was reduced by drought; 620,000 mt in 2003; and 364,000 mt in 2004 when there was a poor, late harvest (Cash 2003a; Sanders 2004). In 2004, fourteen ships visited the port and carried a total of 400,000 mt of grain and other commodities (Sanders 2004).

Most commercial navigation in Hudson Bay and James Bay is related to the annual sealift, whereby the coastal communities are re-supplied with general cargo and fuel during the open water season. The number of sealift vessels visiting each community depends upon community requirements for the year.

In 2003, the Government of Nunavut separated the sealift contracts to supply fuel and dry goods to communities in western Hudson Bay. Northern Transportation Company Ltd. (NTCL), which had supplied these communities by barge from Churchill for much of the past three decades, did not bid on the work (Cash 2003b; Nunatsiaq News 17 January 2003). Nunavut Eastern Arctic Shipping Inc. (NEAS), an Inuit-owned company with its headquarters in Iqaluit, won the contract to ship dry goods; the Woodward Group of Labrador won the contract to ship fuel. NEAS now loads cargo at Valleyfield, Quebec to supply communities in the Canadian eastern Arctic, including those along the Quebec and Nunavut coasts of Hudson Bay (http://www.neas.ca/). Goods are transported to Hudson Bay in two ships; the M/V Umiavut, which is a multi-purpose container vessel, strengthened for heavy cargoes (LOA 113.6 m; draft 8.54 m; cargo capacity 11,840 m^3 or 9,587 tonnes deadweight) and the M/V Aivik a heavy lift vessel (LOA 109.9 m; draft 5.92 m; 13,388 m^3 or 4,860 tonnes deadweight). Both vessels had three sailings in 2003 and again in 2004, with the first vessel arriving in eastern Hudson Bay in mid-July and the last leaving western Hudson Bay in mid-October. Fuel oil, transported to Churchill by rail from the Shell refinery in Fort Saskatchewan, is delivered to the Kivalliq communities by Woodward's double-hull, ice-breaking tanker Mokami. The tanker has fully segregated ballast and is rated ice class 1A Super. (http://www.nnsl.com/ops/sea.html).

The void left in regional shipping by closure of NTCL's Churchill-based barge operation was filled by Moosonee Transportation Limited, which has provided coastal shipping services to communities in James Bay from its base in Moosonee for the past 25 years (http://www.mtlmoose.com/). In 2004, the company operated two tugs and three barges, each with a cargo capacity of 1000 tonnes. Dry goods transported to Churchill by rail were barged to Arviat, Whale Cove, Rankin Inlet, Chesterfield Inlet, Repulse Bay, Coral Harbour, Baker Lake, and Fort Severn. The first barge was scheduled to sail from Chuchill on July 19th for Arviat and the last on September 2nd for Fort Severn. The barges overwinter Moosonee or Wemindji. Cargo is also marshalled at warehouses in Moosonee, Wemindji and Chisasibi, and transported to the other communities in James Bay and southern Hudson Bay—west to Fort Severn and north to Puvirnituq, with occasional trips to other ports in Hudson Bay or Hudson Strait.

The Port of Churchill is the only deepwater port on Hudson Bay or James Bay. It is linked to southern Canada by the Hudson Bay Railway (HBRY), which is owned by OmniTRAX Inc. and services communities and resource-based industries in northern Manitoba (http://www.omnitrax.com/hbry.shtml). Major rail customers include Hudson Bay Mining & Smelting, Tolko Industries, the Canadian Wheat Board, and merchandisers of specialty crops. Wheat and barley marketed by the Canadian Wheat Board and specialty crops are exported through the Port of Churchill, which is the railway's northern terminal. Other major commodities handled by HBRY include ores and concentrates, copper and zinc metal, logs, kraft paper, lumber, petroleum products and general merchandise. Scheduled intermodal service is operated. Passenger service is provided under contract with VIA Rail Canada.

The Port offers four deep-sea berths, including one tanker berth, and can take vessels with a cargo capacity of up to 57,000 tonnes deadweight (DWT). Its facilities include a grain elevator with storage capacity of 140,000 tonnes (5 million bushels), an 82,000 sq. ft. indoor storage facility, and a petroleum terminal with storage for 50 million litres plus rail and dockside distribution systems for various petroleum products (http://www.omnitrax.com/portservice.shtml). Commodities can be delivered by rail to shipside. The Port is available for shipping and receiving ocean vessels from July until November and has three towing tugs available. Scheduling earlier or later in the season is available by using ice-class vessels or icebreakers. Recently, dredging the harbour, re-equipping the car unloading system, and repairing and strengthening the wharf have improved the Port facility and enabled the loading of panamax size vessels of 50,000 to 60,000 DWT (Omnitrax 2001a). The largest ship loaded by the end of the 2004 shipping season was the MV Invader, which loaded 56,100 tonnes of wheat bound for Egypt (Omnitrax 2001b).

Moosonee is Ontario's only marine port and the terminus of the Ontario Northland Railway, which carries passengers and freight to and from Cochrane (OMNR 1985). While it is the distribution point for supplies destined for places in James Bay and southern Hudson Bay, Moosonee is a shallow-draught port (about 2 m) (Jones 1968; R. Cool, Moosonee Transport Limited, Moosonee, pers. comm. 1992). It has limited cargo-handling capability, and deep-draught vessels cannot approach closer than about 30 km--unlike the port of Churchill. This problem is common to most communities in James Bay, so that deep-draught vessels anchor well off the settlements and transport their cargoes to jetties or beaches using powered barges.

Until recently, communities along the east coast of James Bay were supplied by barge from Moosonee and over winter roads. Chisasibi was the first James Bay community to be connected to the south by a permanent all-weather road, followed by Wemindji and Eastmain in 1995, and by Waskaganish (since 2000). These communities are now supplied largely by truck and are less reliant on cargo barged from Moosonee. On the Ontario side of James Bay, winter roads connect Moosonee to Moose Factory, Fort Albany, Kasechewan, and Attawapiskat (http://www.mndm.gov.on.ca/mndm/nordev/PDFs/winterroads0304eng.pdf). The winter road from Shamattawa, Manitoba to Fort Severn, Ontario is being extended to Peawanuck, which is connected by a winter trail to Winisk Harbour. These roads are passable by tractor train for about three months each winter (OMNR 1985).

Communities along the Hudson Bay and James Bay coasts are accessible by scheduled aircraft and receive supplies throughout the year by air, particularly perishables. Churchill and communities in the Kivalliq Region of Nunavut are serviced by a number of regional carriers, including: Calm Air, First Air, Kivalliq Air, and Skyward Aviation. Fort Severn, Ontario is serviced by Bearskin Airlines. Air Creebec serves the James Bay communites in Ontario and Quebec, and Peawanuk near the Ontario coast of Hudson Bay. Air Inuit serves the communities in Nunavik. Most, if not all, of the communities also have facilities for docking floatplanes.

Alterations to the ecosystem resulting from marine transportation include the construction of deep-water port facilities at Churchill and smaller docking or beaching facilities at the other coastal communities. The latter typically consist of gravel "push outs" at the barge landing area, with adjacent cargo martialling areas. In 1977-8, Churchill Harbour and its approach were deepened using a suction dredge and clam dipper (Macdonald and Erickson 1981). An ocean dumping permit was issued allowing the movement of up to 1,300,000 cubic yards at a rate of 4000-7000 cubic yards per day. Monitoring was carried out to ensure that cadmium levels, which were thought to be high in the sediment, did not exceed the ocean-dumping maximum of 0.6 $\mu g \cdot g^{-1}$. Cadmium levels in the sediment removed, which consisted mainly of coarse sand, were well within acceptable limits. The dredged sediments were dumped near the coast and further offshore across the peninsula from the harbour. The harbour was dredged again in 2000, using clamshell and shovelfront (closed bucket) dredges (Canadian Environmental Protection Act, 1999, Permit No. 4543-2-02882).

Vessel traffic on Chesterfield Inlet and Hudson Bay is likely to increase over time both for community re-supply as populations grow, and for shipment of product to market if mineral resources in Kivalliq and along the Hudson Bay Arc are developed. The magnitude of any increases and shipping routes are unknown--in some cases aircraft may take the place of ships. There is potential for oil spills during community re-supply, introduction of toxicants or foreign species through bilge cleaning, and disturbance to marine mammals and seabird colonies by tourists. These concerns are not new or unique to the region. Potential problems can be minimized by education and the enforcement of existing regulations, which prohibit environmental pollution, species introductions, and disturbances to wildlife. Community re-supply personnel are trained in emergency response procedures in the event of oil spills.

There have been a number of shipwrecks in the region, most of which have been destroyed by ice or dismantled for parts (Table 15-9). In 2002, mariners on Hudson Bay were still being cautioned that there was no description of coastal tracks on the east side of Hudson Bay due to inadequate chart coverage, the scarcity of soundings, and the possibility of uncharted dangers (NIMA 2002). They were were also cautioned that many of the islands in James Bay had not been accurately located, and that their charted positions could not be relied upon. There are vivid accounts of the epic journey of the survivors of the Eldorado, a Révillon Frères ship that sank off Chisasibi in 1903 (Upton 1968), and of the discovery of the Fort Churchill, a Hudson's Bay Company ship that was stranded on the Belchers in 1913 (Renouf 1921; Cameron 1948). According to Inuit oral tradition, Europeans shipwrecked on the Belchers were massacred (Saladin d'Anglure 1978).

In 1971-2, divers located two ships, tentatively identified as the Hudson Bay Company exploration frigate Albany and the New England whaler Orray Taft, in the harbours of Marble Island (Smith 1971; Smith and Barr 1971; Martin 1979). Little is known of the condition of the former, which sank in 1719; the latter remained afloat for at least a year after it was damaged and likely offers little worthwhile historical salvage (Martin 1979). It may offer interesting diving opportunities, since it is located near shore in 12 m of water.

In the 1970's, extensive studies were conducted in the Kivalliq Region to assess the feasibility of a pipeline to transport natural gas from the Arctic to southern markets. South of Boothia Peninsula, three alternative pipeline routes were considered, the "Prime" route which passed southward through the region west of Baker Lake, the "Coastal" route which crossed Chesterfield Inlet and passed southward between Kaminak Lake and the coast, and the "Quebec" route which crossed northern Hudson Bay to the Quebec mainland via Southampton, Coats, and Mansel islands (Boyd et al. 1978). Most environmental studies were conducted on the "Prime" route of the "Polar Gas Pipeline" under either the "Polar Gas Environmental Program" (e.g., Hatfield et al. 1978) or the "Arctic Islands Pipeline Program" (e.g., Lawrence et al. 1978; Allan and Hogg 1979) (Figure 15-11). The project did not proceed, in part because the pipeline in the High Arctic could not be buried deeply enough to avoid damage from iceberg scour in coastal waters.

Table 15-9. Ships wrecked in Hudson Bay or James Bay. The Hudson's Bay Company Archives "Ships Histories" reference a wealth of unpublished archival material on many of the ships. Published reference materials are listed.

Ship	Description	History	References
Albany	Wooden sailing frigate of 100 tons. Last Ca pt. George Barlow.	Two Hudson Bay Company ships (see also Discovery) under the command of Captain James Knight were sent to Hudson Bay "discover gold and other valuable commodities". Late in the fall of 1719 they entered the harbour between Quartzite and Marble islands and the larger ship was badly damaged. The crews built a house, and some lived until the summer of 1721 with periodic help from visiting Inuit. In 1767, Hearne (1795) saw the bottoms of the hulls in 5 fathoms of water near the head of the harbour and found the house. He returned the ship's figurehead and canons to the HBC.	Hearne (1795), Neatby (1968), Smith and Barr (1971), Ross and Barr (1972).
Alette	Steam freighter (?). Last Captain Robertson.	Unable to unload her cargo at Port Nelson, she struck ice near Mansel Island in Hudson Strait and returned to Port Nelson. She was beached 4.5 miles downstream from the main camp on 16 October 1913. A hole was dynamited in her number 1 hold side to stop a smoldering coal fire and the cargo was salvaged during the winter.	Malaher (1984).
Ansel Gibbs	Wooden bark (barque). Last Captain Thomas McPherson.	New England whaler. Blown onto the rocks west of the entrance to the inner harbour of Marble Island on 18 October 1872 when her anchor line parted in a storm. She broke up quickly leaving her crew few provisions. Ten crewmen died while wintering on the island in the Orray Taft. The rest were returned to New Bedford aboard the Abie Bradford.	Martin (1979).
Cam Owen	Single-decked, two masted, carvel built, 340-ton wooden brigantine with a crew of 13. Last Master John Hawes.	Hudson Bay ship. Built at Grand River, PEI, in 1883. Wrecked on the rocks 15-20 mi. S of Cape Churchill in a heavy gale on 30-31 August 1886. The hulk was carried out to sea by ice and wind in 1896.	McTavish (1963), The Beaver: Sep. 1932, p. 32.
Cearense	Steam freighter (?)	Ran aground fifteen miles downstream from Port Nelson during a storm on 12-13 September 1913. Her cargo was salvaged the following spring but she was broken up by a storm in September 1916.	Malaher (1984)
Discovery	Wooden sloop of 40 tons. Last Commander David Vaughn.	See Albany.	See Albany.
Effort	Wooden sailing vessel chartered by the Hudson Bay Company.	Left York Factory 17 September 1858 for Montreal. Lost enroute. See below "unidentified".	
Eldorado	Motor sailing vessel, 820 tons. Last Capt. William Berry.	Chartered by Révillon Frères in August 1903 to establish posts at Fort George, Rupert House, Moose Factory, Hannah Bay, and Fort Albany. Drawing 16' of water and carrying 1450 tons of cargo she was larger than any ship the HBC had sent into James Bay. The Eldorado was wrecked on a reef and lost 9 miles out of Fort George. The 47 passengers and crew made an epic journey of 270 miles by boat through James Bay and 500 miles by canoe along the Moose and Abitibi rivers to safety. The wreck set back Révillon Frères plans in the region 3 yrs.	Upton (1968).
Eskimo	Motor vessel.	Trapped in the ice in 1955 near Moosonee by an early freeze-up. Sometimes is visible at low tide downstream from Moosonee.	Two-Bay Enterprizes Ltd., Moosonee, tour brochure.
Esquimaux	Wooden brigantine of 123 tons. Last Master William Taylor Butterwick.	Supply vessel (chartered?) operating between London and posts in James and Hudson bays. Lost on voyage from York Factory to Churchill 20-26 October 1836, in heavy ice and fog--rudder froze. Wrecked 25 mi ENE of the Cape Marsh beacon and 15 mi. WSW of of C. Tatnam, 4 mi. offshore in 3 fathoms at high water. Wreck likely destroyed by ice.	
Expectation	Wooden ketch. Last Capt. Richard Lucas.	An interloper outfitted by a syndicate, which included Charles Boone (former MP) and Thomas Phipps, to trade in James Bay and possibly to recover furs salvaged from the wreck of the Prudent Mary and hidden by her mate (Capt. Lucas). Captured in 1683 by Capt. Nehemiah Walker of the HBC, who wrecked his prize on Charlton Island while attempting to sail her to the Bottom of the Bay. The capture resulted in a long, drawn-out lawsuit against the HBC.	Rich (1958).
Fort Churchill	Wooden motor sailing ketch, 56 tons. Last Capt. Jens Ole Neilsen.	Hudson's Bay Company ship. Built at Porthleven, Cornwall and registered at Falmouth in July 1913. Arrived in York Factory late in the fall of 1913 only to be torn from her moorings in the Nelson River estuary by a severe storm. She was not located until April 1915, following Inuit reports of a vessel stranded on the Belcher Islands. Refloated and towed to Moose Factory for repairs, she served as supply vessel in Hudson Bay and later James Bay until 1939, when she was laid up at Moose Factory. Two years later she was burnt.	Renouf (1921), Cameron (1948).

Ship	Description	History	References
Fort Severn	Two-masted, carvel built, 91-ton wooden schooner with a 95 HP auxiliary diesel. Last Skipper Isaac Barbour.	Built for Révillon Frères by J.A. Weingart, Shelburne, NS in 1924. Taken over by Hudson Bay Company in 1926 and operated as supply vessel for James and Hudson bay posts until 1950. Put into ballast, towed out to Button Bay and sunk in 1952.	Moccasin Telegraph: Dec. 1952, p. 23; Spring 1944, p. 8.
Fort York	Wooden motor schooner of 94 tons. Last Commander R.H. Taylor.	Built at Porthleven, Cornwall in 1914. Serviced Hudson Bay posts in the Nelson River district from 1914-1930. She was deliberately run aground near Severn on 27-28 September 1930 during hurricane force winds to "protect life and property", and declared a total wreck. A 1951 photo showed the hulk well up on the mud flats. It was burned soon after.	Kirkland (1935, p. 66), Harding (1920).
H.M.S.Hampshire	Wooden sailing frigate with 52 guns. Last Commander John Fletcher.	Sent with Owners Love, as convoy for Hudson's Bay and Dering. Sunk by D'Iberville's Pelican near York Factory on 5 September 1697, with 290 men aboard.	Douglas and Wallace (1926).
Hudson's Bay (Royal Hudson's Bay)	Wooden sailing frigate of 150 tons with 32 guns. Last Commander Nicholas Smithsend.	Built in 1698. Engaged in a sea battle with D'Iberville's Pelican in 1697, and was forced to surrender, a helpless wreck. The hulk was beached 20 mi. east of Fort York and James Knight's men salvaged timbers from the wreck in 1715-16.	
Ithaca	Steel steam freighter.	British steamship built at Trois Rivière, Quebec in 1922. On 14 September 1960, enroute to deliver equipment to Rankin Inlet her rudder broke in a gale and she was stranded near Bird Cove about 17 km east of Churchill.	http:/www.churchillmb.net/~cccomm/pintrest.htm
Lady Head	Wooden barque, 1050 tons. Last Capt. John Graham Ford.	Purchased by HBC in 1865 from the builders, George and John Mills, of Southwick. Named after the wife of Sir E.W. Head, Governor of the HBC. Served as supply vessel for Moose Factory from 1865-75 and 1886-1903, and sailed between London and Victoria, B.C. in the intervening years. In September 1903, returning from Charlton, struck the Gasket Shoals at night in a gale and was abandoned, a total loss.	See also photos in Cotter (1934) and Upton (1968).
Mary [I]	Wooden frigate. Last Capt. James Belcher.	Ran aground on the Weston Islands, north of Charlton Island, on its homeward voyage in August 1724. Most of the furs were lost; the passengers and crew 'with much hazard came to Albany Fort in their Boates' and remained there the whole year consuming provisions.	Rich (1958); Davies and Johnson (1965).
Mink	Wooden brigantine, 92 tons. Last Capt. John Taylor.	Hudson's Bay Company ship built by James Turner in 1874. Served in James Bay from 1874-1903, delivering supplies and gathering fur returns for Moose Factory. Replaced by the Inenew in 1903, she was beached at high tide a few miles from Rupert House.	See also photos in Cotter (1934) and The Beaver Dec. 1926, p. 28.
North Star	Motor vessel.	Struck a rock pinnacle north of Grey Goose Island.	Jones (1968).
Orray Taft	Wooden bark (barque) of 134 tons. Last Captain George J. Parker.	New England whaler. Blown ashore on 13 August 1 1872 in the outer harbour at Marble Island when her anchor lines parted in a storm. Beached at the northwest end of the inner harbour. Four crewmen died while wintering on the island. The rest were returned to New Bedford aboard the Glacier, another New England whaler. Subsequent visitors stripped the hulk for lumber and firewood. In 1971, divers located a sunken ship likely the Orray Taft in 12 m of water. It's structure was covered in algae.	Smith and Barr (1971), Martin (1979).
Pery (Perry)	Wooden frigate. Last Capt. Richard Ward.	HBC ship. Ran aground and sank in the Albany River in September 1711. Some of her cargo for the James Bay posts was salvaged.	Davies and Johnson (1965).
Prince Rupert I	Wooden sailing frigate of 75 tons. Last Commander Zacchariah Gillam.	Built in 1670. Served as a supply ship. Drift ice caused her to drag anchor, drift out to sea, and sink with 9 crew and Gillam aboard on October 21, 1682. John Bidgar, newly appointed Governor of York Factory, and the remaining crew were ashore. They were taken prisoner by Radisson.	Newman (1985).
Prudent Mary	Wooden sailing vessel of about 140 tons. Last Capt. Richard Greenway.	Chartered by the HBC to carry furs from Charlton I. to England. In 1680, loaded with furs, she struck a reef on Trodely Island (Tetherley's Island), just north of Charlton Island, and was lost. Most of the furs, some isinglass and fittings were salvaged and her Captain and crew arrived safely at Fort Albany. The partially submerged hulk was burnt in 1681.	Kenyon (1986); Rich (1958).
Sorine	Wooden barque, 6-700 tons. Last Captain Hans Andersen.	The Sorine was a Danish barque chartered by the HBC in London to deliver supplies to their posts in James Bay. She was damaged by ice in Hudson Bay while returning in ballast and run aground on the eastern tip of Charlton Island for the winter of 1910. There she stayed.	Anderson (1961); photos of the ship and hulk in Williams (1939).
Stork	Wooden barque of 479 tons. Last Captain N.E. Freakley	Built in Gothenburg in 1880, purchased by the HBC in 1904. Bound for England she was forced by ice to return to Charlton Island only to strike a submerged reef and sink near Lisbon Rock about 22 km from Charlton Island, during a blizzard. The Captain and crew abandoned ship on 11 October 1908, and arrived in Moose Factory the day before freeze-up. Part of the decking could be seen near Moose Factory in 1939.	HBC Archives: Search File A12/FT 289/1; Williams (1939); Williamson (1983).
unidentified	Wooden sailing vessel.	Belcher Islands Inuit describe a massacre of white sailors in the past, possibly the crew of the Effort, which left York Factory for Montreal on 17 September 1858, and disappeared--or perhaps some earlier ship.	Saladin d'Anglure 1978b.

Figure 15-11. Proposed Polar Gas Pipeline route (from National Atlas of Canada 1978).

15.4 TOURISM

The effects of marine ecotourism are low at present but may be increasing. The main activity takes place at Churchill where visitors come from around the globe to see migratory birds (spring-fall), beluga whales in the estuary (summer), and polar bears (fall). At least one of the tour companies operating in the Churchill River estuary uses a boat with silenced engines and jet-drives to avoid disturbing or injuring the whales (http://www.seanorthtours.com/).

Outfitters at the other Hudson Bay communities will take visitors on local sightseeing trips to see Arctic wildlife: walrus at Coats Island and polar bears at Wager Bay are particular favourites, and diving expeditions are available at Churchill and Sanikiluaq.

Cruise ships such as the Akademik Ioffe, a refitted Russian polar research vessel (http://www.adventurecanada.com/), and international tours also visit northwest Hudson Bay in the summer (http://www.windowsonthewild.com/wow/Walrus/walrus.htm). Concern has been expressed that tourist overflights in the Cape Henrietta Maria area may stampede walrus herds into the water and cause calf mortality (C. Chenier, DNR Cochrane, ON pers. comm. 2003), and boat disturbances are a concern in the Coats Island area.

Marine tourism in the James Bay region is limited. From mid-June through mid-September, Two Bay Enterprises Ltd. operates daily cruises from Moosonee on their luxury cruise vessel the M.V. Polar Princess. The vessel travels upstream to Fossil Island and downstream to Shipsands Island and James Bay. Elsewhere in James Bay and Southeastern Hudson Bay tourists can charter smaller boats and freighter canoes.

15.5 MUNICIPAL ACTIVITIES

The main impacts of municipal developments on the marine environment are related to shoreline development, disturbances and waste disposal, all of which occur mostly in the immediate vicinity of the communities. The impacts of shoreline development are limited by the small regional population (see Chapter 4 (Climate), Table 4-3 for data) and by ice push and scour that largely precludes development of the intertidal zone and foreshore. There are gravel "push-outs" to facilitate barge offloading and harbour facilities at the Port of Churchill, but otherwise most of the community infrastructure is located away from the shoreline. Visual and noise disturbances related to the presence of communities and to coastal transportation, by boat in summer or snowmobile or Bombardier in winter, may affect marine mammals in particular. These impacts cannot readily be separated from those of harvesting activities. They may have played a part in the abandonment of some *uglit* (haulouts) by walruses (see Marine Mammals Section 9.8).

The development of infrastructure to deal with sewage and wastewater is an ongoing problem throughout the region. Permafrost and cold temperatures make it difficult and very expensive to develop piped collection networks and construct stable lagoons, and can cause condensation problems in secondary treatment facilities.

There is a 65% failure rate among lagoons in Nunavut that, in most cases, are not designed to handle the demands of growing populations (http://www.gov.nu.ca/finance/bp/2004/cgs.pdf). Some of the communities, such as Churchill, Rankin Inlet, and Peawanuk have piped sewage systems while others, such as Coral Harbour, still pick up sewage by truck. Where a lagoon is damaged, or lacking, bacterial and chemical contaminants may be discharged directly into the sea or flow overland to the water's edge. Fortunately, the combined effects of low temperature and high salinity kill most organisms that cause human disease in a short time. Initiatives are underway at Rankin Inlet, and elsewhere, to improve sewage treatment.

15.6 GRAND CANAL SCHEME

A Great Recycling and Northern Development (GRAND) Canal scheme has been proposed which would involve the construction of a dam across James Bay, so the area could serve as a reservoir from which freshwater could be diverted south into the United States (Kierans 1984, 1987, 1988). The potential effects of such a project on the oceanography of Hudson Bay, productivity of James Bay, world climate, native peoples, etc. cannot be adequately predicted (Milko 1986; Gamble 1987, 1989; Berkes 1989) and must not be underestimated. Modelling studies suggest that transforming James Bay into a massive freshwater lake would disrupt coastal currents, delaying ice melt and leading to colder, wetter coastal conditions (Rouse et al. 1992). They also suggest that the decrease in salinity would alter salt marsh vegetation in northern James Bay (Price et al. 1992). These effects are just the tip of the ecological iceberg.

15.7 SUMMARY

Relatively few people live along the vast coastline of Hudson Bay and James Bay and very little development has occurred. Hydroelectric development is the activity with the greatest existing and potential impact on the marine ecosystem over the short and, perhaps, long term. Mineral developments, transportation, municipal waste disposal, and tourism also have the potential to impact the marine environment. The impoundment of James Bay to provide water for the United States (GRAND Canal Scheme) is unlikely, but it would have important and far-reaching effects on the marine ecosystem. Development of a pipeline to transport natural gas south from the Arctic is also unlikely, but it too could affect the marine ecosystem.

Hydro-electric developments have altered the flow regimes of the La Grande and Eastmain rivers, which drain into James Bay, and of the Churchill and Nelson rivers, which drain into southwest Hudson Bay. The longterm impacts of these diversions on the marine environment are unknown and, in the case of the latter, impossible to assess in the absence of baseline marine data.

In 1980, 80% of the flow from the Eastmain River was diverted into the La Grande River, and seasonal runoff was impounded so that it could be released to produce electricity in the winter. Under these regulated conditions the natural spring freshet into James Bay does not occur at either river. Because of the flow diversion, the plume from the Eastmain River is much reduced and there are intrusions of saline water up to 10 km upstream, year-round. While the size and shape of the summer plume from the La Grande River are essentially unchanged by development, the area of its under-ice plume has trebled. The winter discharge of freshwater from the La Grande River into James Bay increased from 500 $m^3 \cdot s^{-1}$ under natural conditions, to over 4000 $m^3 \cdot s^{-1}$ following the diversion during peak power production. The plume can extend 100 km northward under the landfast ice of James Bay, and further increases in midwinter flow will lead to dilution of the nearshore surface waters in southeastern Hudson Bay. The biological effects of these changes are not well understood. Slightly elevated mercury levels have been found in the flesh of marine fishes within 10-15 km of the river mouth.

In 1976, 75% of the flow of from the Churchill River was diverted into the Nelson River to produce hydroelectric power. This has reduced runoff from the former while increasing it in the latter. The impacts of these changes on the estuaries cannot be assessed in the absence of pre-project data. Grande rivière de la

Baleine and the Moose, Albany, Canipiscau, and Opinaca rivers have also been affected by diversion or hydroelectric development.

The effects of hydroelectric development on the offshore surface waters are not well understood. Continued development may increase the winter surface salinity gradients and currents in James Bay. Modelling by Prinsenberg and Danard (1985) suggests that the surface temperature is buffered somewhat against man-made changes. They predicted that a decrease in surface temperature, such as might be caused by hydroelectric development of surrounding watersheds, would gradually be offset by the stabilizing effects of the colder water on the overlying air. This would act to decrease wind stress and increase the heat flux into the water. The reverse should be true in the case of an increase in water temperature. Ice-ocean modelling studies by Saucier and Dionne (1998) suggest that the bay-wide effects of the power plants are small compared with the natural variablility observed in the ice cover. The environmental impacts of altering the seasonal runoff regime on oceanographic conditions in the North Atlantic are uncertain and controversial.

Quebec Hydro plans future hydroelectric development in southern James Bay, where flow from the Rupert River would be diverted into the Eastmain River. Manitoba Hydro is considering further developments on the Nelson River system, as is Ontario Hydro on the Moose River system. With the exception of the Rupert, the flow regimes of these rivers have already been altered by development.

There are no offshore mineral or hydrocarbon developments in Hudson Bay or James Bay and the only mine on the coast, for nickel at Rankin Inlet, has been closed since the 1960's. The region has a potential for discovery and development of hydrocarbons, base and precious metals, diamonds, asbestos, phosphate, gypsum, limestone, aggregate, and perhaps other minerals and materials. There has been some offshore mineral exploration and oil drilling in southwestern Hudson Bay but to our knowledge no oil or gas discovery has been made, and no exploration is ongoing.

Mineral deposits in the Kivalliq Region that contain gold, base metals, and/or diamonds may be developed over the next decade. They may require expediting services provided by the communities, improved port facilities, and servicing by shipping on Hudson Bay. This would likely increase ship traffic on Hudson Bay, and the potential for the release of contaminants. Development potential along the Quebec coast of Hudson Bay, where exploration is at an earlier stage, is less certain. If development occurs along the Hudson Bay Arc, it too may rely on the coastal communities and Hudson Bay shipping for logistical support. Mining developments inland from the James Bay coast and from southwestern Hudson Bay would likely be less reliant on the coastal communities and transport supplies, materials and products by road or rail.

The impacts of marine transportation are low at present. Annual vessel traffic within Hudson Bay includes freighters that visit the Port of Churchill to load prairie grain and other commodities; ships or coastal barges that re-supply the other communities with food, dry goods, and fuel (sealift); and occasional luxury liners. Despite regular ship traffic to and from the region since the late 1600's, few natural alterations are apparent apart from the Port of Churchill, smaller docking facilities elsewhere, and a few marine hulks. Vessel traffic is confined largely to the open water season so there is seldom a requirement for ice-breaking, which can disrupt marine mammals and harvesting activities. Periodic dredging is required to keep the Churchill Harbour passable to large ships. In 1977-78, monitoring was carried out to ensure that cadmium levels, which were thought to be high in the sediment, did not exceed the ocean-dumping maximum of $0.6\ \mu g \cdot g^{-1}$. In the event, the levels were well within acceptable limits. There is some potential for spills of contaminants, such as oil during re-supply, and for the introduction of foreign organisms when bilges are cleaned. In James Bay, the railway to Moosonee and seasonal or all-season roads to the other communities limit the need for sealift and thereby potential impacts from shipping.

The main impacts of municipal developments on the marine environment are related to shoreline development, disturbances, and waste disposal, all of which occur mainly in the immediate vicinity of the communities. Sparse populations and ice push and scour have limited development of the intertidal zone and foreshore. Visual and noise disturbances from communities, and boat or on-ice transportation, may affect marine mammals in particular. These impacts cannot readily be separated from those of harvesting activities, but may have played a part in the abandonment of some *uglit* (haulouts) by walruses. Initiatives are under way to improve sewage and wastewater treatement facilities. Bacterial and chemical contaminants may be discharged directly into the sea or flow overland to the water's edge where lagoons are damaged or lacking. Fortunately, the combined effects of low temperature and high salinity kill most organisms that cause human disease in a short time.

The effects of marine ecotourism are low at present but may be increasing. The main activity takes place at Churchill where visitors come from around the globe to see beluga whales in the estuary (summer), and polar bears (fall) and migratory birds (spring-fall) along the coast. Outfitters at the other communities will take visitors on local sightseeing trips to see Arctic wildlife; walrus at Coats Island and polar bears at Wager Bay are particular favourites. Cruise ships also visit northwest Hudson Bay in the summer. Concern has been expressed that visitors to Coats Island and the Cape Henrietta Maria area may stampede walrus herds into the water and cause calf mortality.

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16.0 CONTAMINANTS

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Some information has been published describing the chemical contamination of biota from Hudson Bay, especially animals taken by Native people for subsistence consumption (seals, whales, polar bears, birds, fish). The Northern Contaminants Program has issued annual reports describing research on northern contaminants and it has also produced two comprehensive summaries. The second summary was released in March 2003, and some of the illustrations from it provide a timely overview of the state of chemical contamination of the biota of Hudson Bay.

One important question is whether the contamination of physical strata or biological organisms is fully or partially the result of human activity. Residues of synthetic organochlorine compounds have been found consistently in animals from Hudson Bay. These compounds result exclusively from human activities. They are products of 20th-century technology and have no natural sources and no natural background concentrations.

16.1 EVIDENCE OF INPUTS OF SYNTHETIC ORGANIC COMPOUNDS

Some of the most convincing evidence of the impacts of human activities on Hudson Bay and indeed the Arctic in general, derives from studies of synthetic organic compounds. These compounds reach the Arctic by several means but one important pathway is via moving air masses (Figure 16-1). For example, studies of the composition of the air from the Canadian North have consistently identified a wide range of synthetic organic compounds that originate thousands of km away. Figure 16-2 shows the levels of one of the isomers of hexachlorocyclohexane in air from Kinngait (Cape Dorset) in winter of 1994/95 and again in 2000/01. While it is discouraging to find compounds like these in the air of northern communities, it is encouraging to see that the levels measured in 2000/01 were lower than those found in 1994/95. Its two major users, China and the former USSR, discontinued the use of HCH in 1983 and 1999, respectively (CACAR II 2003). These synthetic compounds with little or no history of use in the North have nonetheless appeared throughout the Arctic in air, water and aquatic life.

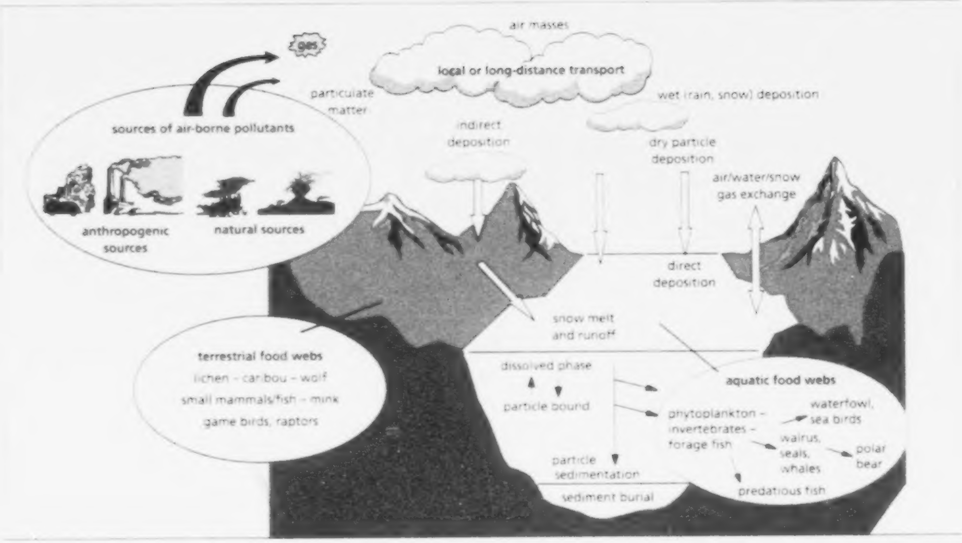


Figure 16-1. Schematic of pathways of transport and accumulation of persistent organic comtaminants and some metals to arctic and marine ecosystems. (From CACAR I 1997, Figure 3.2.1, page 193).

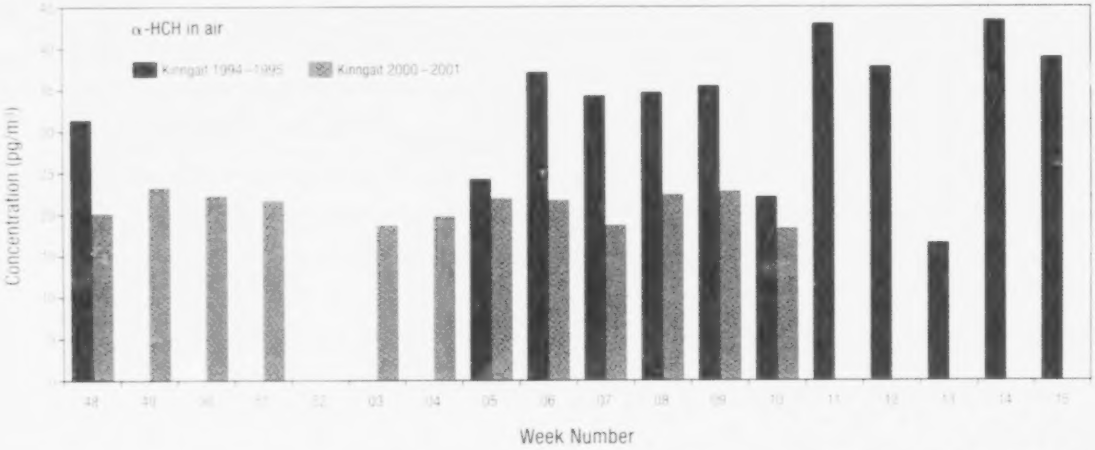


Figure 16-2. HCH in air from Kinngait (Cape Dorset) during the winters of 1994/95 and 2000/01. (From CACAR II 2003 : Physical Environment, Figure B.1.3, page 81).

16.2 EVIDENCE OF IMPACT OF ANTHROPOGENIC ACTIVITIES

Another good example of the impact of human activities is the deposition of cesium-137 (Cs-137) derived from the atmospheric testing of fission bombs. This is illustrated in Figure 16-3. This isotope does not occur naturally. It is formed by the fission of uranium atoms into smaller fragments. The figure shows a sediment profile of Cs-137 (red dots) from southeastern Hudson Bay in 1992 (Lockhart 1998). The Cs-137 must have reached Hudson Bay and other sites throughout the hemisphere with moving air masses. Each point in this graph is the result from the analysis of a slice of sediment from the core starting at the top with the sediment-water interface. The dates shown were calculated from the profile of the natural isotope lead-210 (blue triangles). The peak period for the deposition of bomb isotopes should occur in 1963 and this core shows a broad peak in slices in the 1950s and 1960s. There has been some mixing or vertical movement of Cs-137 within the core otherwise we

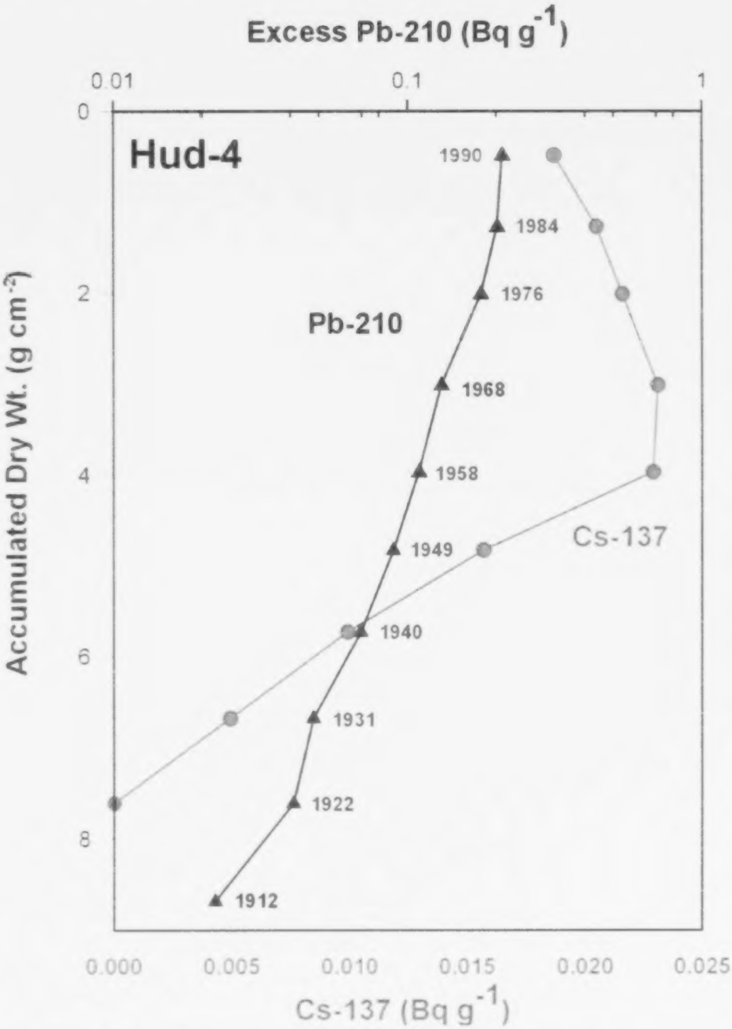


Figure 16-3. **Down core profile of lead-210, a natural radioactive isotope of lead, and cesium-137, a byproduct of atmospheric testing of nuclear bombs, in a sediment core from southeastern Hudson Bay in 1992 (from Lockhart et al. 1998).**

should expect a more rapid decline in slices deposited after peak deposition and we should not expect any in the slice dated at 1931. Nonetheless, the presence of Cs-137 is an unambiguous sign of the presence of products of human activity well removed from the watershed.

In 1992, the Department of Fisheries and Oceans sponsored a workshop to explore the nature of impacts on Hudson Bay with particular attention to hydroelectricity projects (Bunch and Reeves 1992). Several impacts were considered, namely the Great Whale hydroelectricity project in Quebec, the Conawapa hydroelectricity project in Manitoba, mercury contamination, nutrients and suspended matter, impacts on nearshore habitats, freshwater fish, marine mammals, endangered fish stocks, and productivity of marine species. The principal discussion was given to the cumulative impacts of combinations of individual impacts. For example, hydroelectric reservoirs alter the timing of freshwater inflows and that in turn can affect sedimentation, water stratification, temperature, salinity, and ice distribution and quality. These in turn affect the biological communities of benthic and pelagic organisms. More recently Sly (1995) listed a number of human activities within the drainage with potential to exert toxic chemical stress on Hudson Bay (Table 16-1). Most of these activities have some potential to contribute loadings of chemical substances to the drainage basins.

The study of elements in sediments is often more complex than the study of synthetic materials like cesium-137 or organic pesticides. The presence of a natural element is not, in itself, evidence of human activity because many elements are present naturally in soils and sediments. However, human activities often move elements about from place to place in the environment in ways and at rates not found naturally. The questions that arise in cases of suspected contamination by elements are whether the amounts found exceed natural background amounts and what the sources might be. Among the more toxic elements are cadmium, copper, chromium, lead, mercury, and zinc and the metalloids arsenic and selenium. In view of the potential for these elements to produce biological harm, Canada has established Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PEL) (Table 16-2). These guidelines describe levels that should not be exceeded in freshwater and marine sediments in order to avoid biological impacts.

The watersheds draining to Hudson Bay are being changed by human activities, notably population growth and associated business activity, agriculture, hydroelectricity, and climate change. In addition to alterations in watersheds, there is direct loading to the water surface of Hudson Bay by materials dispersed via atmospheric circulation. With the relatively limited attention contaminants have been given in Hudson Bay, existing analyses and those done in the coming few years have 'benchmark' quality that will help to assess the magnitude and significance of future changes.

Chemical contaminants often become incorporated into aquatic sediments. As the sediments accumulate over time, they provide an archive of past and present inputs of the contaminants (e.g., Haworth and Lund 1984). Only a few studies of this nature have been done in Hudson Bay. For example, Hermanson has studied sediment cores from small lakes in the Belcher Islands and reported histories of contamination by several elements (Hermanson 1993).

16.3 PRIMARY OBJECTIVE

The primary objective of this section is to compare the data on several elements reported by Henderson (1989) with Interim Sediment Quality Guidelines that were developed after the thesis was written.

16.4 SECONDARY OBJECTIVE

In addition, the Northern Contaminants Program recently released its summary of research on contaminants in the Canadian North for the past five years. Excerpts from that document and some unpublished data are included to provide a current overview of our knowledge of contaminants in biota.

Table 16-1. Human activities and their potential to exert toxic chemical stress on the Hudson Bay ecosystem (from Sly 1995).

Activity	Potential for impact
forestry	low
agriculture	low
local mining	medium-high
distant mining	low
local oil and gas activity	low - high
distant oil and gas activity	low
pulp and paper	low - medium
local hydroelectricity	medium - high
distant hydroelectricity	low to medium
Transmission (hydroelectricity)	low to medium
Air transport	low
Shipping	low to high
Roadway	low to medium
Rail transportation	low to medium
Construction sites	medium to high
Tourism/Recreation	
Population growth	low to high
LRTAP*	low to high
Global warming	

*Long Range Transport of Atmospheric Pollutants

Table 16-2. Interim sediment quality guidelines (ISQG) for marine sediments in Canada and concentrations described as "Probable effect levels" (PEL).

Element	Interim Sediment Quality Guideline for marine sediments ($\mu g \cdot g^{-1}$ dry weight)	Probable Effect Level for in marine sediment (μg^{-1} dry weight)
Arsenic	7.24	41.6
Cadmium	0.7	4.2
Chromium	52.3	160
Copper	18.7	108
Lead	30.2	112
Mercury	0.13	0.7
Zinc	124	271

Canadian Council of Ministers of the Environment, 2001. Canadian sediment quality guidelines for the protection of aquatic life: Summary tables.

16.5 DATA FROM HENDERSON (1989) PH.D. THESIS

Data presented in the thesis by Henderson (1989) were derived from the analysis of dredge samples of surface sediment collected during several oceanographic surveys of Hudson Bay over the period from 1961 to 1986, mainly with geological objectives in mind. Dredge samples were fractionated into four particle-size classes (Table 16-3). Information was given on geographic position, water depth, and particle-size classes for most samples. The geographic positions where samples were obtained were presented as UTM (Universal Transverse Mercator) coordinates. Since Hudson Bay spans several UTM zones, it was convenient to express the position data in latitude and longitude. UTM coordinates were converted to longitude and latitude coordinates by M. Ouellette, Freshwater Institute, using MapInfo software. The datum used for the conversion was NAD83. Undoubtedly some of the older samples would have been described with reference to the older NAD27 datum and so the positional data listed in latitude and longitude may contain small errors in addition to any present in the original UTM coordinates. In proportion to the size of Hudson Bay, such errors are insignificant.

Table 16-3. Sediment fractions described by Henderson (1989).

Fraction	Description
>2 mm	Weight per cent of total sample larger than 2 mm in size
Sand	Weight per cent sand (0.063 – 2 mm) of matrix fraction < 2 mm
Silt	Weight per cent silt (0.004 – 0.063 mm) of matrix fraction < 2 mm
Clay	Weight per cent clay (<0.004 mm) of matrix fraction < 2 mm

Henderson, 1989, Appendix C

Several elements were analyzed in the clay-size fraction of some of the samples. This sub-set was drawn from samples collected from 1965 to 1986. Since different samples were sometimes analyzed for different variables, there are some variations in the numbers of samples available for pair-wise tabulations and mapping. Some samples were analyzed in duplicate or triplicate and reported more than once in the original tables; in those instances, the first result listed was used and any further replicates were ignored. In a few instances, apparent inconsistencies, probably of typographical origin, were found and were interpreted with the author's best judgment. This resulted in a set of 114 samples widely distributed throughout Hudson Bay for which metals data were available. Data were copied from the original thesis tables into Microsoft Excel, checked manually, and then transferred electronically to a table in Microsoft Access format. Data were sorted and drawn from the Access table as needed. Appendix 5 lists the positions, depths and particle sizes of the sediments at sites for which metals were determined. Appendix 6 lists the concentrations of metals found in the sediments.

Three types of presentation follow:

- tabular comparison with sediment quality guidelines for elements for which these guidelines have been established,
- pair-wise correlation analysis for associations between pairs of elements, and
- spatial distribution maps.

16.6 HENDERSON THESIS DATA AND INTERIM SEDIMENT QUALITY GUIDELINES (ISQG)

The Canadian Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PEL) were listed in Table 16-2. The guideline figures are given in terms of total sediment whereas the figures from Henderson (1989) were for the clay-size particles only. Consequently, a straightforward comparison is not possible. Lacking analyses of the metal content of other sizes of particles, it is not possible to express Henderson's results in the same units as the ISQG. However, it is likely that the error is conservative because metals are usually more abundant in the clay-size particles than in larger particles. Assuming that to be the case, the values from Henderson (1989) are higher than they would be in unfractionated, bulk sediment.

16.7 COMPARISON OF HUDSON BAY VALUES WITH ISQG

Interim Sediment Quality Guidelines have been established for five of the elements reported by Henderson (1989). Table 16-4 shows the number of sediment samples for which the clay-size particles fell in each of the three ranges defined by the ISQG: below the ISQG, between the ISQG and the PEL, and above the PEL.

Sediment quality guidelines have not been established for the remaining metals reported by Henderson (1989). In addition, some comparisons of Henderson's (1989) data are made with the same elements in sediments from lakes and streams, based on the report of many thousands of samples by Painter et al. (1994).

Table 16-4. **Interim sediment quality guidelines (ISQG) and probable effect levels (PEL) for five elements in Canada and numbers of samples in Henderson (1989) in ranges defined by ISQG and PEL.**

Element	ISQG ($\mu g \cdot g^{-1}$ dry weight, whole sediment)	PEL ($\mu g \cdot g^{-1}$ dry weight, whole sediment)	Number Below ISQG (in clay- size fraction)	Number above ISQG & below PEL (in clay-size fraction)	Number above PEL (in clay- size fraction)
Arsenic	7.24	41.6	103	10	1
Chromium	52.3	160	0	78	36
Copper	18.7	108	0	112	2
Lead	30.2	112	5	108	1
Zinc	124	271	4	110	0

16.7.1 Arsenic

Arsenic (As) in 114 samples averaged 3.7 $\mu g \cdot g^{-1}$ with a range of 2 to 77 $\mu g \cdot g^{-1}$. Arsenic values are plotted the maps in Figure 16-4. Most of the samples (92) were reported as 2 $\mu g \cdot g^{-1}$, probably indicating that they were too close to limits of measurement to be reliable. The analytical detection limit for arsenic was given as 5 $\mu g \cdot g^{-1}$ and so relatively little confidence might be given to values tabulated as 2 $\mu g \cdot g^{-1}$. Ten samples fell between the ISQG of 7.64 $\mu g \cdot g^{-1}$ and the PEL of 41.6 $\mu g \cdot g^{-1}$ (Table 16-4). One sample only exceeded the PEL and that one may have been an analytical or typographical error since it was far outside the range of the other samples. That sample (65TH 0466, Appendix 6) was reported to be 77 $\mu g \cdot g^{-1}$, well beyond the range of all the others. (The sample with the second highest level was only 17 $\mu g \cdot g^{-1}$). Although the values given by Henderson as 2 $\mu g \cdot g^{-1}$ may be open to some question quantitatively, there is still information in them. Results below the detection limit of 5 $\mu g \cdot g^{-1}$ are also below the ISQG of 7.74 $\mu g \cdot g^{-1}$, hence most samples contained arsenic in the clay-size fraction well below the ISQG. Twenty-two samples only had arsenic at 5 $\mu g \cdot g^{-1}$ or greater. Comparing the results with the ISQG, 11 samples exceeded 7.61 $\mu g \cdot g^{-1}$, and one of them exceeded the PEL.

Arsenic in the clay size particles had no statistical correlation to water depth and little relationship to other metals in the same particles (Appendix 7). (As was weakly correlated with potassium.) Considering the geographic distribution of points, the sites where arsenic exceeded the ISQG (Figure 16-4 (left panel)) were mostly in the central area of Hudson Bay; there was no concentration of points that might suggest a potential source of sediment enriched in arsenic. The bars on the map in Figure 16-4 (right panel) show more clearly that the points with the highest concentrations of arsenic are located mostly in the central part of Hudson Bay.

Painter et al. (1994) reported arsenic levels in 17,088 lake and stream sediment samples from widely scattered areas of Canada. The median value was 1.9 $\mu g \cdot g^{-1}$ and the 95th percentile was 22 $\mu g \cdot g^{-1}$. Their data were presented as coloured areas on maps (Figure 16-5) and also as a graph. From their graph, it is evident that about 90 per cent of samples had arsenic values below the ISQG. Figure 16-5 shows the distribution of arsenic values includes some regions in Hudson Bay drainage. Most of the values were below 6 $\mu g \cdot g^{-1}$ with the exception a striking anomaly on central Baffin Island called the Foxe Fold Belt where values were often above 21 $\mu g \cdot g^{-1}$. Virtually all values from the large region west of Hudson Bay, much of it in Churchill drainage, were below 6 $\mu g \cdot g^{-1}$.

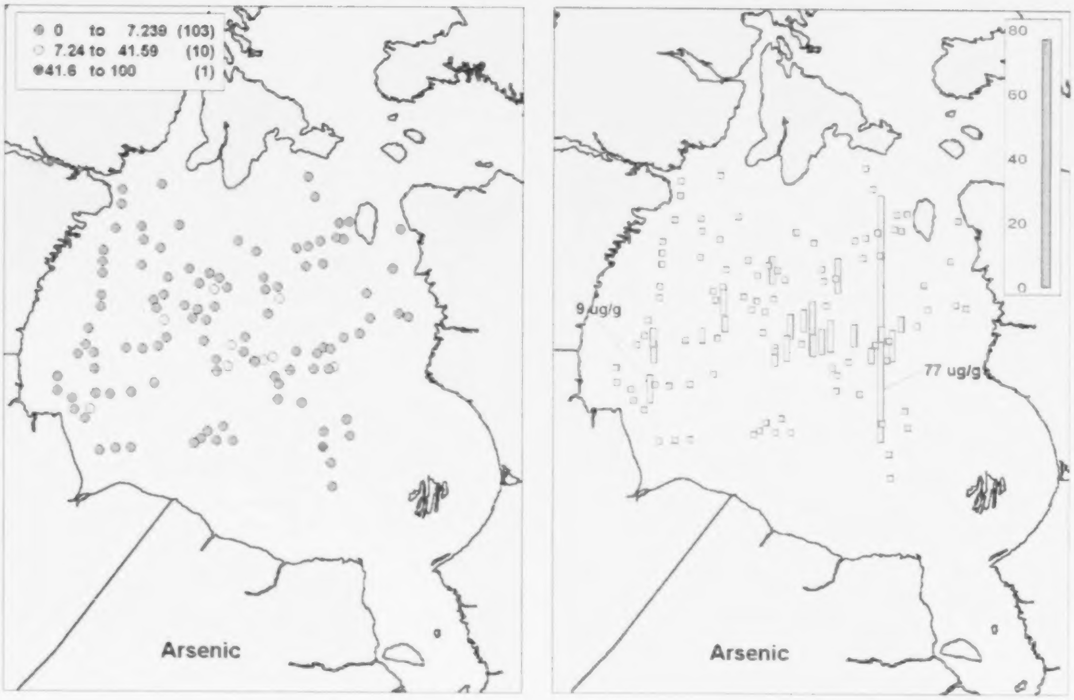


Figure 16-4. Arsenic (μg·g^{-1} dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges are those from the Canadian ISQG (=7.24 μg·g^{-1} dry weight whole, unfractionated sediment) and PEL (=41.6 μg·g^{-1}). Bar heights are scaled to concentrations of arsenic.

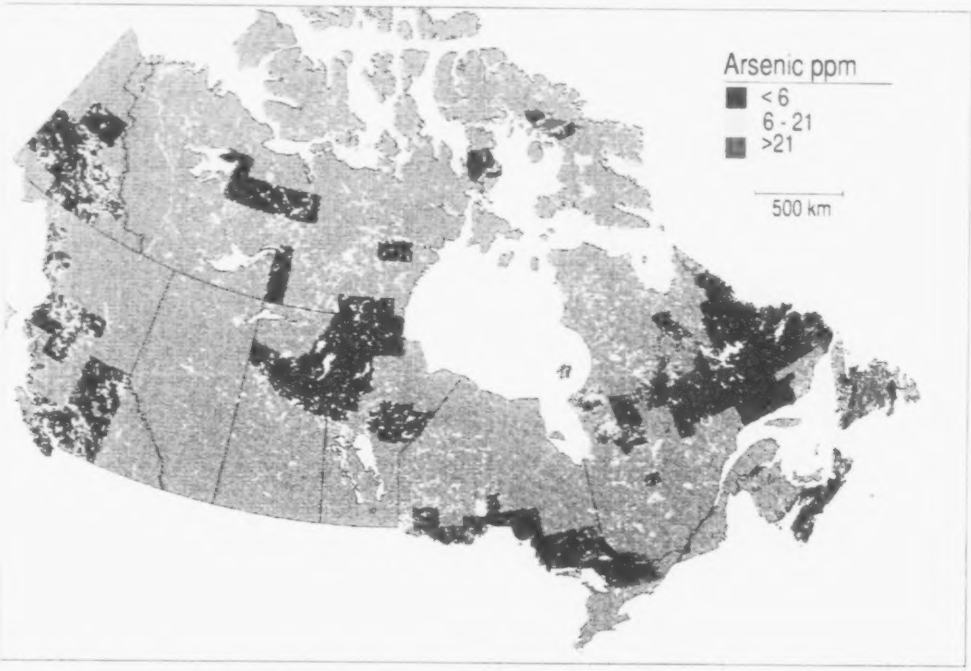


Figure 16-5. Arsenic in lake and stream sediment samples. (From Painter et al. 1994, p. 223).

It seems unlikely that the amounts of arsenic found currently in Hudson Bay clay-size sediments represent a significant risk to the biological community there. If whole, unfractionated sediment were analyzed, it would probably have lower concentrations of most elements than the clay-size particles reported by Henderson (1989). It seems likely that the levels reported indicate a natural background for arsenic in fine sediment particles distributed by natural processes.

16.7.2 Chromium

The 114 samples analyzed for chromium (Cr) ranged from 99 to 274 µg·g^{-1} with a mean value of 152 µg·g^{-1}. No samples contained chromium below the ISQG concentration of 52.3 µg·g^{-1}. Most of the samples (78) fell between the ISQG value and the PEL value of 160 µg·g^{-1} and 36 exceeded the PEL (Table 16-4). The detection level for chromium was 1 µg·g^{-1} and so all the values were well above the detection level and should be reliable. Chromium levels tended to be higher in shallow water than in deeper water (Appendix 7, r = –0.27). Chromium levels correlated with a suite of other elements, (Mg, Fe, Ni, Cu, Zn, Pb). It was negatively correlated with depth, Ca and Mn. The geographical distribution of samples in each concentration range is shown on the map in Figure 16-6. Most of the sites with chromium over the PEL were offshore from the southwestern part of Hudson Bay suggesting the possibility of chromium-enriched sediments originating from drainages entering Hudson Bay from the west.

With the clay-size sediments consistently exceeding the ISQG and even the PEL, it is desirable to obtain new analyses of bulk, unfractionated sediment in order to compare results directly with the ISQG and PEL. It is not known whether the existing levels in the sediment represent a risk to the biota of southwestern Hudson Bay. A more rigorous interpretation of the results for chromium (and other metals) will await further analysis of unfractionated sediment, and characterization of the oxidation state(s) of chromium in the sediments.

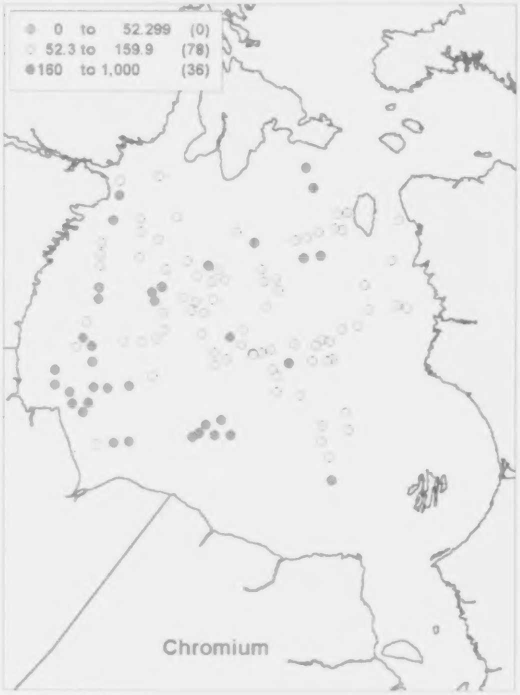


Figure 16-6. **Chromium (µg·g^{-1} dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges are those from the ISQG (=52.3 µg·g^{-1}) based on unfractionated, whole sediment, and the PEL (=160 µg·g^{-1}).**

Painter et al. (1994) provided some graphical information on chromium in 65,948 samples of lake and stream sediment. The median value was 32 µg·g^{-1} and the 95th percentile was 120 µg·g^{-1}. About 70% of sediment samples fell below the ISQG. Relative to these whole sediment values, the clay-size fraction in sediment from Hudson Bay is enriched in chromium.

16.7.3 Copper

Copper (Cu) concentrations in 114 samples of clay-size sediment averaged 41 µg·g^{-1} with a minimum of 22 µg·g^{-1} and a maximum of 170 µg·g^{-1}. There were no values under the ISQG of 18.7 µg·g^{-1}; almost all values (112 of 114) fell between the ISQG and the PEL of 108 µg·g^{-1} (Table 16-4). Two sites had copper concentrations over the PEL. Cu values correlated negatively with depth but not with other metals. Geographically the points are plotted in Figure 16-7 (left panel) and all but two of the points on the map appear the same because the ranges were selected to describe the ISQG and PEL. Figure 16-7 (right panel) presents the same data as bar graphs so that high and low values within a range are more apparent. In general, the highest values were found off the west coast of Hudson Bay near the Churchill River. Henderson (1989) noted the presence of copper enrichment in several places between Chesterfield Inlet and Rankin Inlet, and also north of Arviat. She suggested that the distribution of copper can be explained by sediment transport offshore from the District of Keewatin.

Painter et al. (1994) reported copper in 253,682 samples of lake and stream sediments. The median concentration was 20 µg·g^{-1}, slightly over the ISQG of 18.7, and the 95th percentile value was 76 µg·g^{-1}. The distribution map by Painter et al. (1994) for copper in lake and stream sediments is shown in Figure 16-8. Areas of enriched copper in sediments of Foxe Basin drainages were identified, one on central Baffin Island and the other on the Melville Peninsula. The units for the Painter et al. (1994) study are directly comparable with the ISQG and so all of the red and yellow areas in Figure 16-8 and some of the green points exceed the ISQG.

As with chromium, it is desirable to determine copper in Hudson Bay sediments in the same units of measurement as the ISQG. The clay-size particles exceed the ISQG and some also exceed the PEL. However, the sediments may not exceed these criteria on a bulk sediment basis. *McCrea* et al. (1984) determined total copper in 18 dredge samples of bulk surficial sediments from five Ontario rivers at points just before they enter Hudson Bay or James Bay. Copper concentrations in those samples averaged 6.2 µg·g^{-1} and ranged from 3 to 19 µg·g^{-1}, all lower than those found in the clay-size sediments of Hudson Bay.

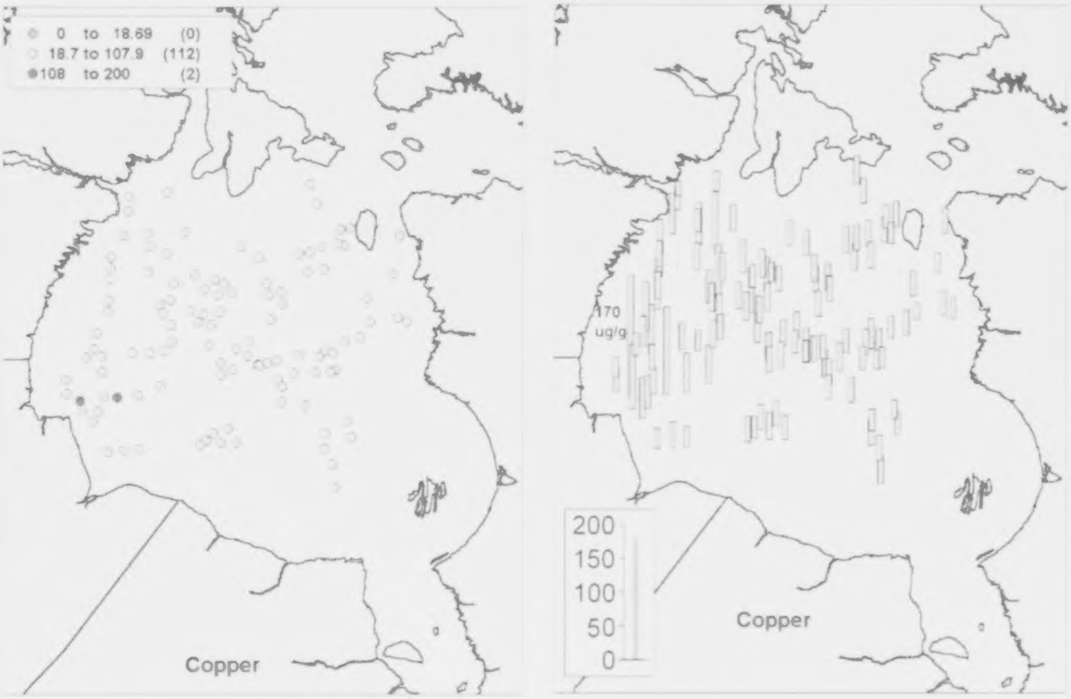


Figure 16-7. **Copper (µg·g^{-1} dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges are those from the ISQG (=18.7 µg·g^{-1}) and the PEL (=108 µg·g^{-1}). Bar heights are scaled to concentrations of copper.**

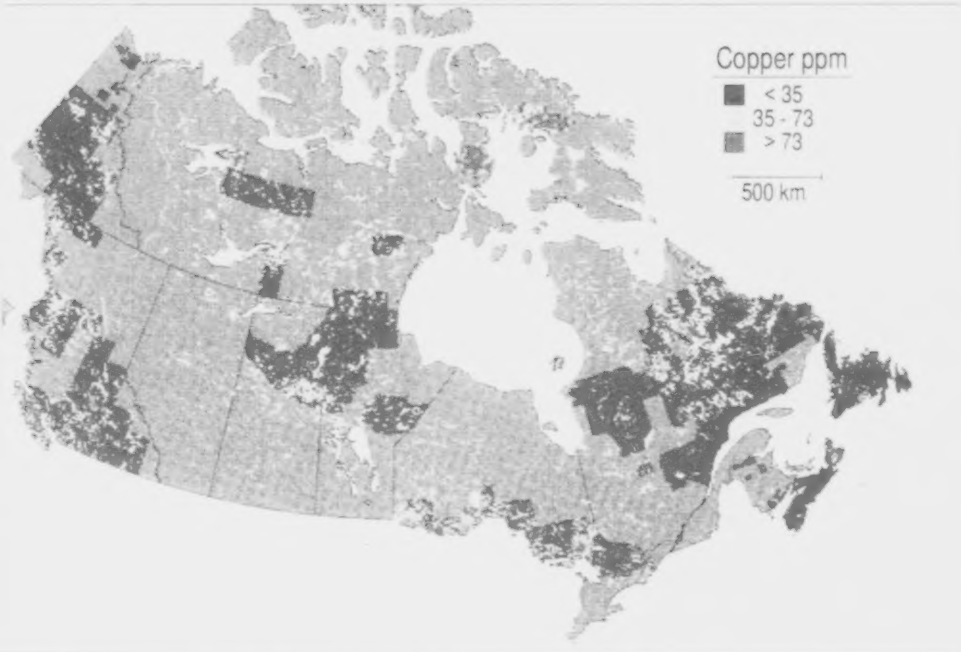


Figure 16-8. Copper in lake and stream sediment samples (From Painter et al. 1994, page 223).

16.7.4 Lead

Lead (Pb) in clay-size sediment particles ranged from 27 to 137 $\mu g \cdot g^{-1}$ with a mean value of 45 $\mu g \cdot g^{-1}$. Five sites had lead at concentrations lower than the ISQG of 30.2 $\mu g \cdot g^{-1}$ and 108 sites fell between the ISQG and the PEL of 112 $\mu g \cdot g^{-1}$ (Table 16-4). One site only exceeded the PEL. There was no relationship between lead in the sediment and the depth of water at the sites. Lead levels correlated with a few other metals (Co, Cr, Ni, Zn, Appendix 7). The geographical distribution of lead levels is shown in Figure 16-9 (left panel). This figure does not display the pattern of lead levels well because almost all the samples fell within the range between the ISQG and the PEL. Figure 16-9 (right panel) shows the concentrations of lead as bar graphs with no obvious geographic clustering of high or low values.

We have some additional data on profiles of lead in sediment cores collected in southeastern Hudson Bay in 1992 and 1993 (Figure 16-10). The values for lead in these cores ranged up to about 12 $\mu g \cdot g^{-1}$. The lead-210 profile for dating the layers of core Hud-4 was shown in Figure 16-1 and it had the expected exponential decline in Pb-210 with depth. Core Hud-4 also showed an increase in stable lead near the top of the core. Given the dating profile in Figure 16-1, the most likely interpretation of the stable lead profile in Figure 16-10 (right panel) is that inputs of lead to that site increased during the 20th century relative to pre-industrial times. The other two lead profiles shown in Figure 16-10 (Hud-10 and Fogo-4) give no indication of increasing amounts of lead in the upper slices. These two cores (Hud-10 and Fogo-4) had more extensively mixed upper layers (possibly by sediment movements and biological mixing) and so gradients in stable lead would have been unable to form or, if formed, would have been obscured or eliminated by mixing. Core Hud-4 is similar to a core from Imativik Lake in the Belcher Islands where Hermanson (1993) found that inputs of lead have increased about 3.5-fold over historical inputs. Hermanson (1993) also noted that the anticipated decline in inputs of lead due to the phasing out of lead additives to motor fuels in the early 1970s has apparently not been reflected in the core from Imativik Lake. We have results similar to those from Imativik Lake with sediment cores from Hawk Lake and Far Lake at the Saqvaqjuac research site on the west coast of Hudson Bay just north of Chesterfield Inlet (Lockhart, unpublished data). Furthermore, stable lead isotope analysis of the Far Lake core indicates that some of the inputs of lead are of anthropogenic origin (P. Outridge, unpublished data).

Painter et al. (1994) described lead in 253,846 samples of lake and stream sediments. The median value was 6 $\mu g \cdot g^{-1}$ and the 95th percentile was 25 $\mu g \cdot g^{-1}$. Figure 16-11 shows the distribution of lead in lake and stream sediments reported by Painter et al. (1994) and their results for regions near Hudson Bay and Foxe Basin are quite similar to those for copper. Given the ISQG of 30.2 $\mu g \cdot g^{-1}$, clearly very few samples of sediment from lakes and streams exceed the ISQG. McCrea et al. (1984) analyzed for lead in the sediments of the Moose, Albany, Attawapiskat, Moose, and Severn rivers at points just before entering the sea and found an average concentration of only 11.4 $\mu g \cdot g^{-1}$ (range 7-17 $\mu g \cdot g^{-1}$), below the values for clay-size sediment from Hudson Bay.

The most likely conclusion is that Hudson Bay has received inputs of anthropogenic lead over the last century probably from atmospheric fallout. The clay-size sediments frequently contain concentrations of lead above the ISQG. Probably this same argument applies to rivers flowing into Hudson Bay but the concentrations of lead in bulk sediments from the Ontario rivers were relatively low.

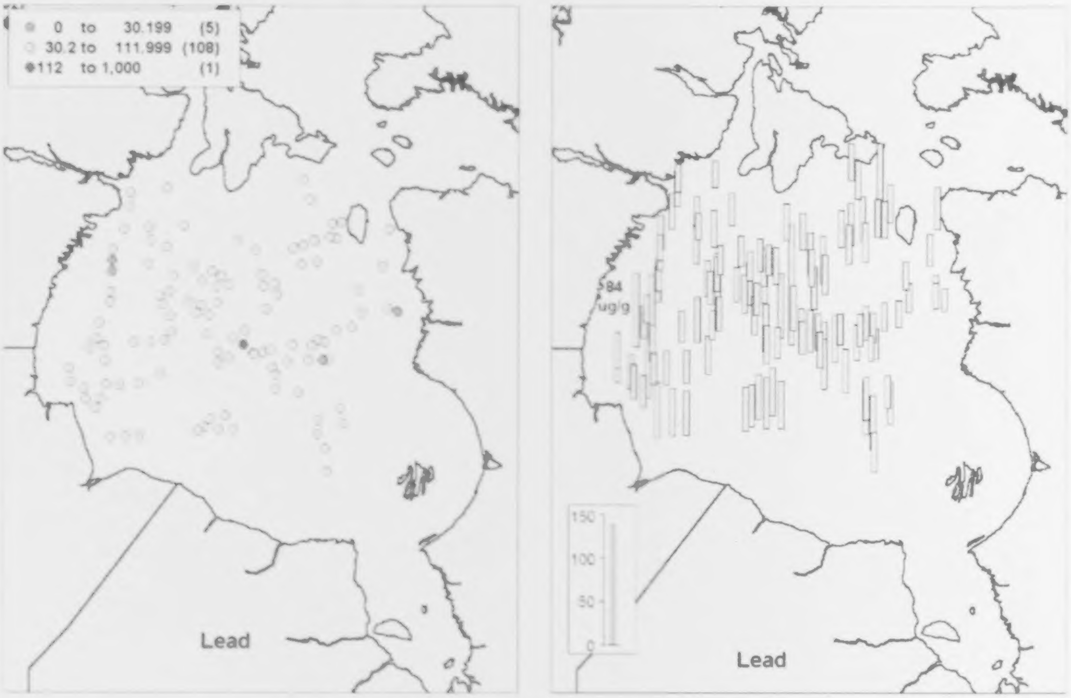


Figure 16-9. **Lead ($\mu g \cdot g^{-1}$ dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges are those from the ISQG (=30.2 $\mu g \cdot g^{-1}$) and the PEL (=112 $\mu g \cdot g^{-1}$). Bar heights are scaled to concentrations of lead.**

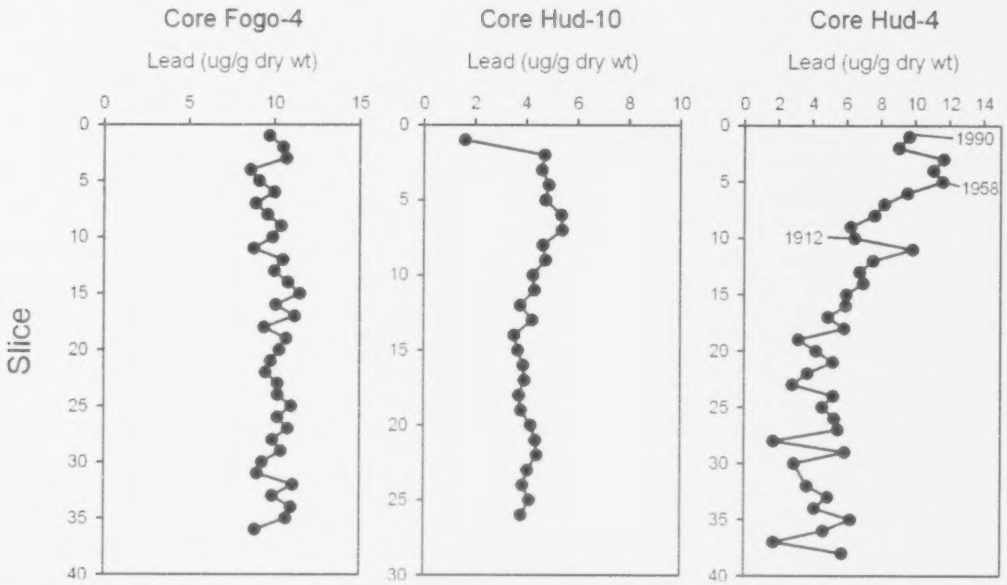


Figure 16-10. Down-core profiles of lead in three sediment cores from southeastern Hudson Bay. Cores Hud-4 and Hud-10 were collected in 1992 and core Fogo-4 was collected in 1993 (L. Lockhart, unpublished data). Sampling locations are shown in Figure 16-24.

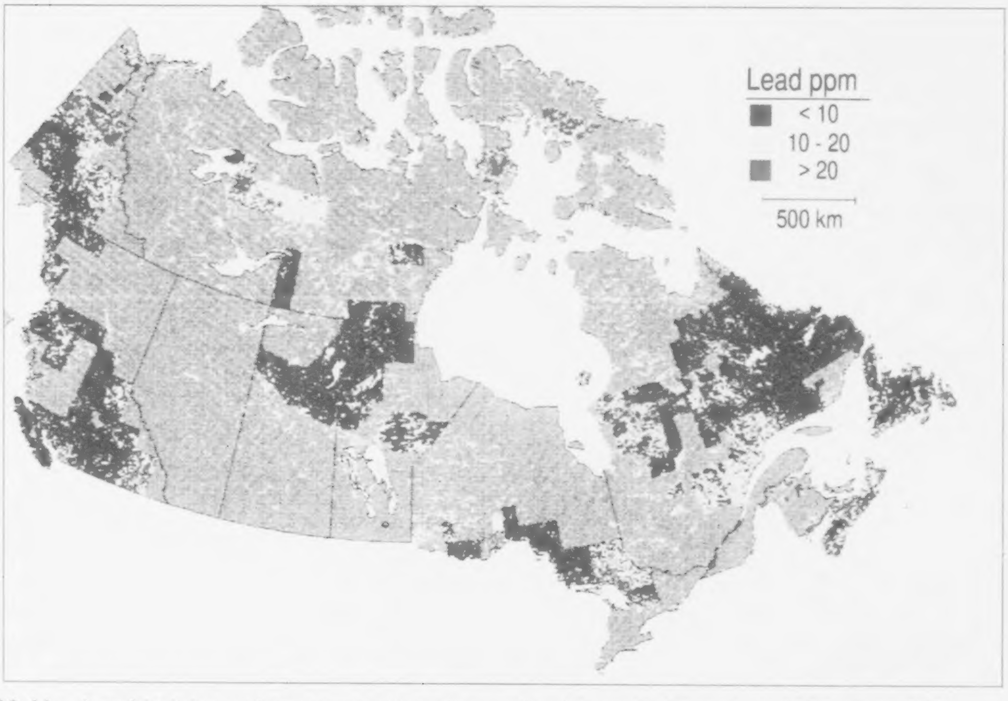


Figure 16-11. Lead in lake and stream sediment samples (From Painter et al. 1994, page 223)

16.7.5 Zinc

The range in concentrations of zinc (Zn) was from 109 µg·g^{-1} to 227 µg·g^{-1} with a mean value of 167 µg·g^{-1}. Four samples only had zinc concentrations below the ISQG of 124 µg·g^{-1}. All remaining samples exceeded the ISQG but were below the PEL of 271 µg·g^{-1}. No samples exceeded the PEL (Table 16-4). Zinc levels correlated strongly with a number of other metals, notably Mg, Co, K, Fe, Cr, and Ni (Appendix 7). Zinc correlated negatively with Ca but had no correlation with depth. The geographic distribution of zinc levels is shown in Figure 16-12 (left panel). As with some other metals, most of the samples fell in a single range of values and so a second map has been included showing the values as bar graphs (Figure 16-12 (right panel)). There is no obvious clustering of high or low zinc values.

Painter et al. (1994) summarized 256,216 sediment results for zinc and found the median concentration to be 69 µg·g^{-1} with the 95th percentile value of 191 µg·g^{-1}. From the graphical presentation by Painter et al. (1994)(Figure 16-13), about 70 per cent of the values would fall below the ISQG level of µg·g^{-1}. The geographic distribution shown in Appendix 7 shows a large region southeast of Hudson Bay with values under 60 µg·g^{-1} (green). However, other areas in the Hudson Bay/Foxe Basin drainage are mostly yellow (60-120 µg·g^{-1}) or red (>120 µg·g^{-1}). Judging from the graphical presentation by Painter et al. (1994))(Figure 16-13), about 70 per cent of lake and stream sediment samples contained zinc at concentrations below the ISQG. McCrea et al. (1984) also measured zinc in the sediments from the five Ontario rivers. Zinc concentrations ranged from 23 to 83 µg·g^{-1} with a mean of 34.1 µg·g^{-1}. As with copper and lead, zinc concentrations from the rivers were also well below those from the clay-size sediments from Hudson Bay.

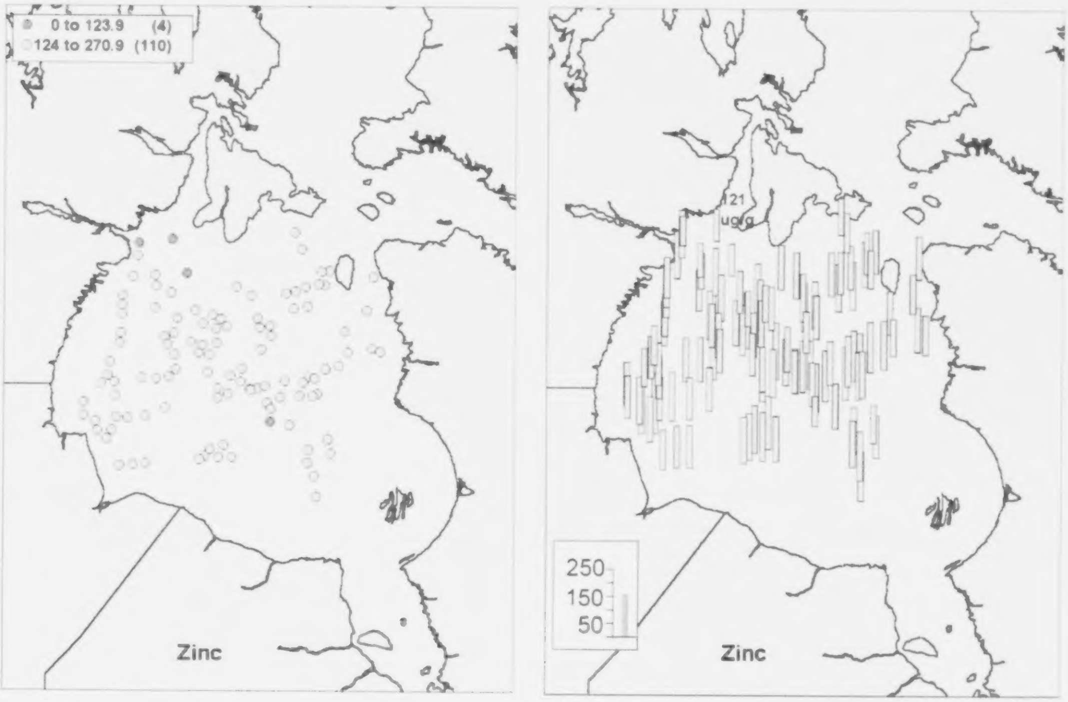


Figure 16-12. **Zinc (µg·g^{-1} dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges are those from the ISAG (=124 µg·g^{-1}) and the PEL (=271 µg·g^{-1}). Bar heights are scaled to concentrations of zinc.**

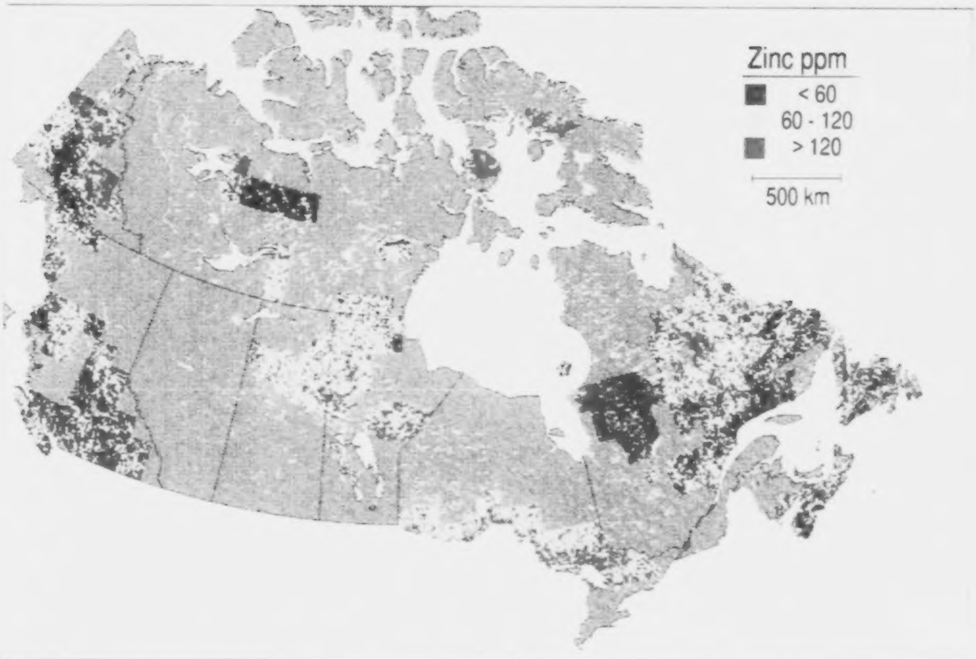


Figure 16-13. Zinc in lake and stream sediment samples (From Painter et al. 1994, page 223).

16.8 METALS FOR WHICH ISQG VALUES DO NOT APPLY

No Interim Sediment Quality Guidelines have been established for the remaining metals reported by Henderson: aluminum, calcium, cobalt, iron, magnesium, manganese, molybdenum, nickel, and potassium. Several of these are major components of the earth's crust and the concept of ISQG does not apply. Others are trace metals and ISQG values have not been established. The concentration ranges for these metals are shown in Table 16-5. The geographic distributions of these metals in the clay-size sediments of Hudson Bay are shown in Figure 16-14 through Figure 16-23. Extensive discussion of the distribution of these metals for which no guidelines have been established is beyond the scope of this report. The reader is referred to Henderson (1989) who points out that "the distribution of base metals can be related both to provenance and diagenetic processes." The major elements (measured in units of per cent by weight) all vary by about 3-fold from the minimum to the

Table 16-5. Ranges and means of metals in sediment samples from Hudson Bay. (Data from Henderson 1989).

Element	Units	n	Minimum	Maximum	Arithmetic Mean	Crustal abundance*
Aluminum	Per cent	114	3.15	9.78	6.53	8.1
Calcium	Per cent	114	0.8	5.54	1.78	3.6
Iron	Per cent	114	2.68	7.5	5.06	5.0
Magnesium	Per cent	114	1.37	3.93	2.64	2.1
Potassium	Per cent	114	1.69	4.96	3.34	2.6
Cobalt	$\mu g \cdot g^{-1}$	114	13	53	26.9	
Manganese	$\mu g \cdot g^{-1}$	114	0.04	1.0	0.12	
Molybdenum	$\mu g \cdot g^{-1}$	114	0.5	12	3.37	
Nickel	$\mu g \cdot g^{-1}$	114	51	107	74.0	

*Average crustal abundance figures from Strahler and Strahler 1978, page 202 maximum value except for calcium which varies by about 7-fold. Somewhat different spatial patterns are evident for the different major elements. These elements, along with oxygen, silicon, and sodium, are the major components of the earth's crust. Their presence and levels in the sediments of Hudson Bay do not infer anthropogenic impacts. Henderson (1989) conducted 13 mineralogical analyses of clay-size particles and most of those samples contained dolomite, feldspars, quartz, illite, kaolinite, and chlorite; some also contained calcite, amphibole, and smectite. The elements found in these minerals are shown in Table 16-6.

Table 16-6. Major elements found in the minerals identified in the clay-size fraction of surficial sediments from Hudson Bay. Sources for this information were web sites as listed.

Mineral	Major elements present in mineral
Dolomite	Calcium, magnesium, carbon, oxygen ([illegible])
Feldspars	Potassium, sodium, calcium, aluminum, silicon, oxygen ([illegible])
Quartz	Silicon, oxygen ([illegible])
Illite	Potassium, magnesium, aluminum, iron, silicon, hydrogen, oxygen ([illegible])
Kaolinite	Aluminum, silicon, oxygen, hydrogen ([illegible])
Chlorite	Magnesium, iron, aluminum, silicon, oxygen, hydrogen ([illegible])
Calcite	Calcium, carbon, oxygen ([illegible])
Amphibole	Iron, magnesium, calcium, aluminum, silicon, oxygen, hydrogen ([illegible])
Smectite	Sodium, calcium, aluminum, magnesium, silicon, oxygen, hydrogen ([illegible])

16.9 MAJOR ELEMENTS (AL, Ca, Mg, Fe, K)

16.9.1 Aluminum

Aluminum (Al) was found in the clay-size sediment at about 3 to 10 per cent by weight with a mean of 6.5 per cent. Aluminum comprises about 8.1 per cent by weight of the earth's crust and so its average concentration in Hudson Bay fine sediments is slightly below its crustal average. Five of the minerals identified in the clay-size fraction contain aluminum (Table 16-6) and so its concentrations are expected to be relatively high. Concentrations of aluminum did not correlate with water depth although they correlated statistically with other major elements, magnesium, iron and potassium and with trace elements cobalt and nickel (Appendix 7). Aluminum is relatively uniformly distributed with high and low values scattered throughout the area sampled (Figure 16-14). Aluminum in the river sediments reported by McCrea et al. (1984) ranged from 0.9 to 4.5 per cent.

16.9.2 Calcium

Calcium (Ca), another major element, averaged almost 1.8 per cent by weight of the clay-size sediment with a range from 0.8% to 5.54% (Table 16-5). It was enriched in samples from the northern areas of Hudson Bay relative to those from central and southern areas (). Henderson (1989, page 142) reported that northern Hudson Bay sediments are characterized by high proportions of Paleozoic limestone clasts in the fine gravel fraction and so enrichment in calcium in that area is not surprising. As with aluminum, five of the mineral components of the clay-size fraction contain calcium and so its high overall abundance was expected. The crustal average for calcium is about 3.6 per cent by weight and so its average concentration in these fine sediments was lower than its crustal average. There was no correlation between calcium and depth. However, there were a number of negative pair correlations between calcium and other elements (Cr, Zn, Co, Fe, K, Ni; Appendix 7).

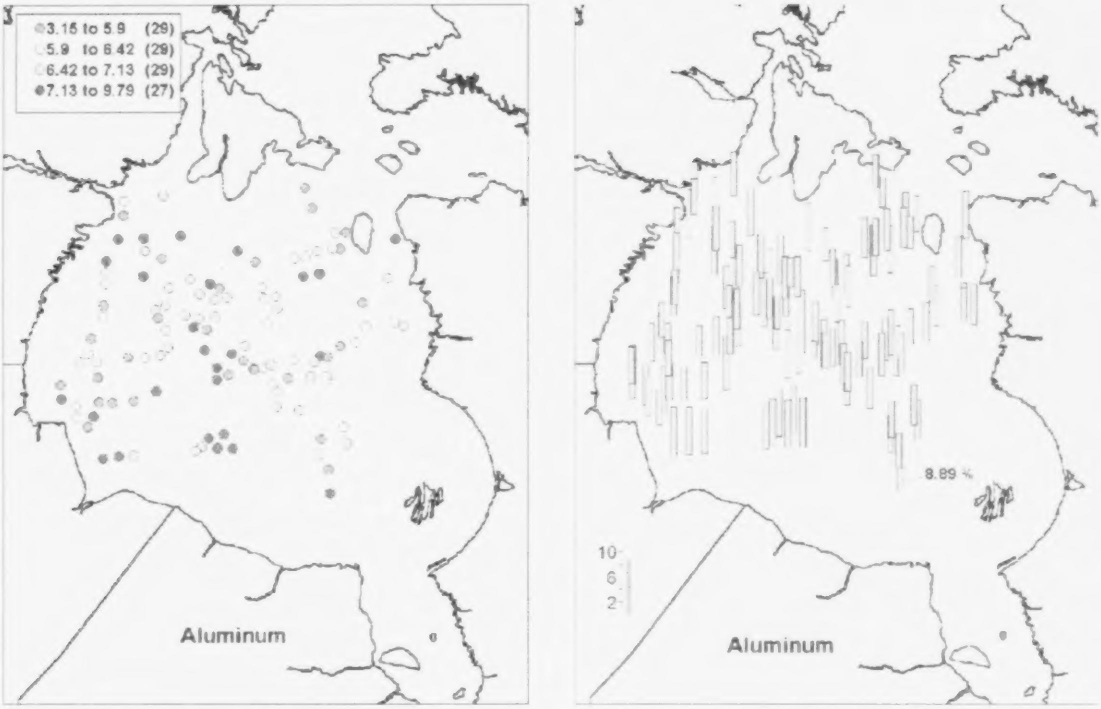


Figure 16-14. **Aluminum (per cent dry weight) in clay-size particles of sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to concentration of aluminum (right).**

16.9.3 Magnesium

The average crustal content of magnesium (Mg) is 2.1 per cent by weight and concentrations in the fine sediments ranged from 1.37 to 3.93 per cent (Table 16-5) with a mean of 2.6 per cent. Its geographic distribution in the clay-size fraction (Figure 16-16) is somewhat similar to that for calcium but the higher values are shifted southward. Magnesium is abundant in five of the minerals listed in Table 16-6. Magnesium was not related to depth, but correlated positively with other elements (Appendix 7).

16.9.4 Iron

Iron ranged from 2.68 to 7.5 per cent with a mean value of 5.06 per cent, almost the same as the average crustal abundance of this element (Table 16-5). Iron occurs in illite and chlorite, minerals identified in the clay-size fraction of sediment (Table 16-6). Iron content was not related to depth but it was related statistically to most of the other elements. Its distribution (Figure 16-17) shows most of the high values in the central area of Hudson Bay, in common with several other elements. Like the other elements, iron was also less abundant in the river sediments than in the clay-size fraction from Hudson Bay. McCrea et al. (1984) found an average of 1.32 per cent iron in the river samples with a range from 0.56 to 3.2 $\mu g \cdot g^{-1}$.

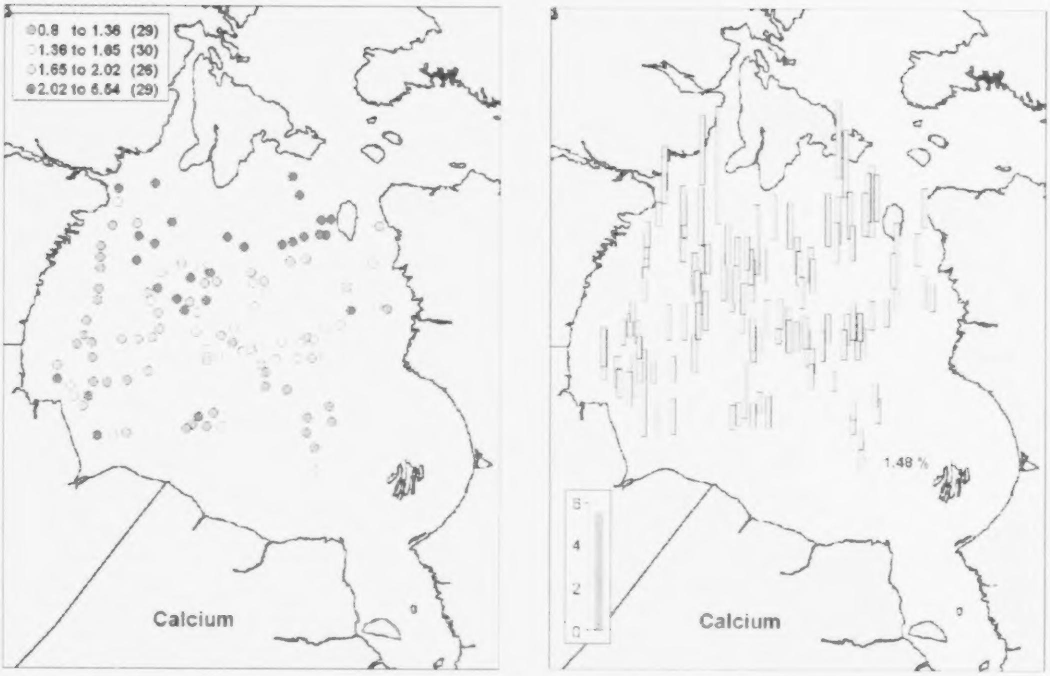


Figure 16-15. Calcium (per cent dry weight) in clay-size particles of sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to concentration of calcium (right).

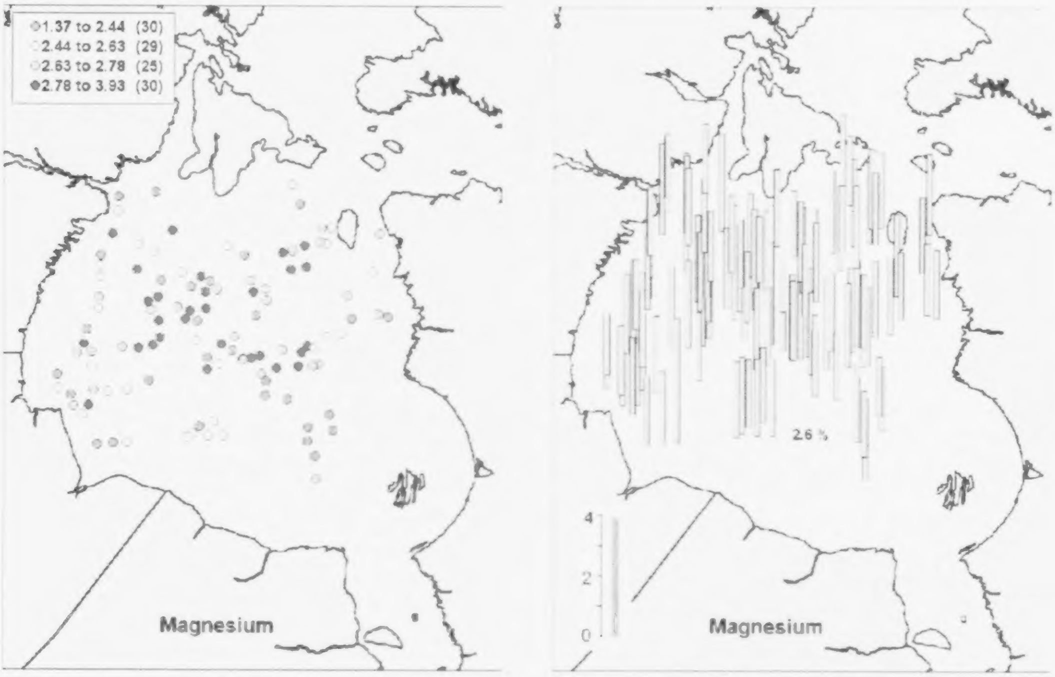


Figure 16-16. Magnesium (per cent dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to concentration of magnesium (right).

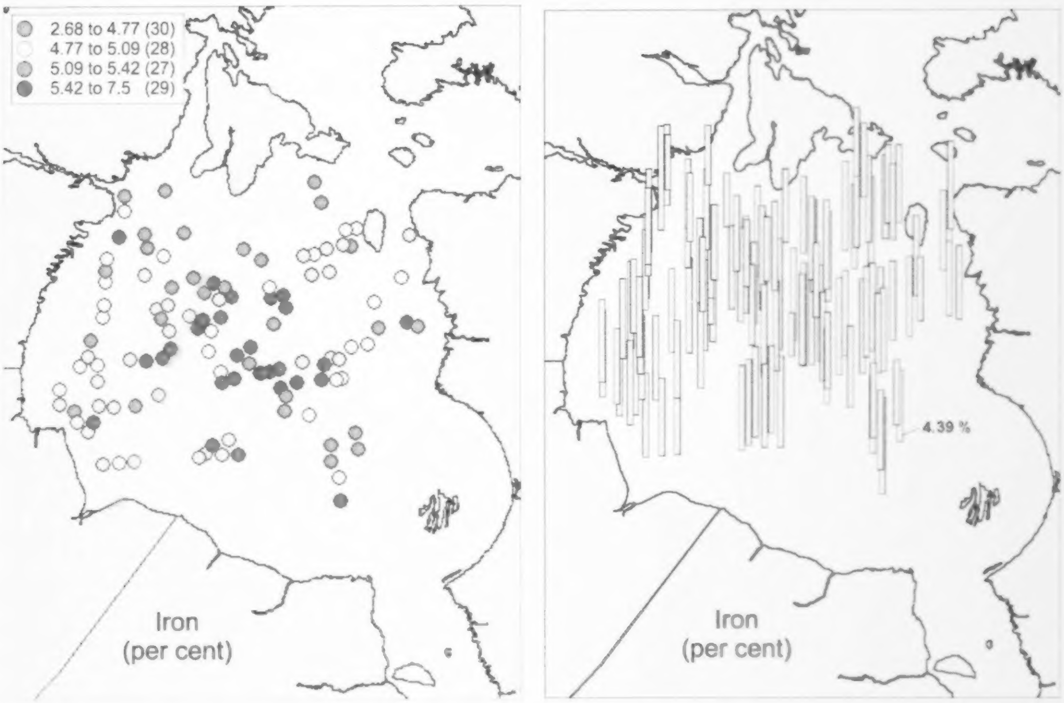


Figure 16-17. **Iron (per cent dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to concentration of iron (right).**

16.9.5 Potassium

Potassium, the last of the major elements analyzed, was found at concentrations from 1.69 to 4.96 per cent with a mean of 3.34 per cent, somewhat above the crustal average of 2.6 per cent (Table 16-5). Potassium is present in feldspars and illite, two of the minerals most commonly identified in the clay-size fraction (Table 16-6). Statistically, potassium had no relation to water depth, but it correlated strongly with several other elements, especially iron (Appendix 7). Geographically, it had a cluster of high values west of the Belcher Islands unlike the other major elements (Figure 16-18) but somewhat like the trace element, nickel.

16.10 REMAINING ELEMENTS (Co, Mn, Mo, Ni)

16.10.1 Cobalt

The crustal abundance of elements is unhelpful as a guide for trace elements. Cobalt (Co), a trace element, was present in the 13-53 $\mu g \cdot g^{-1}$ range with a mean value of 27 $\mu g \cdot g^{-1}$ (Table 16-5). Most of the high values for cobalt were in the central part of Hudson Bay (Figure 16-19), in common with a number of other trace elements. Concentrations of cobalt correlated positively with water depth and with several other elements (Appendix 7).

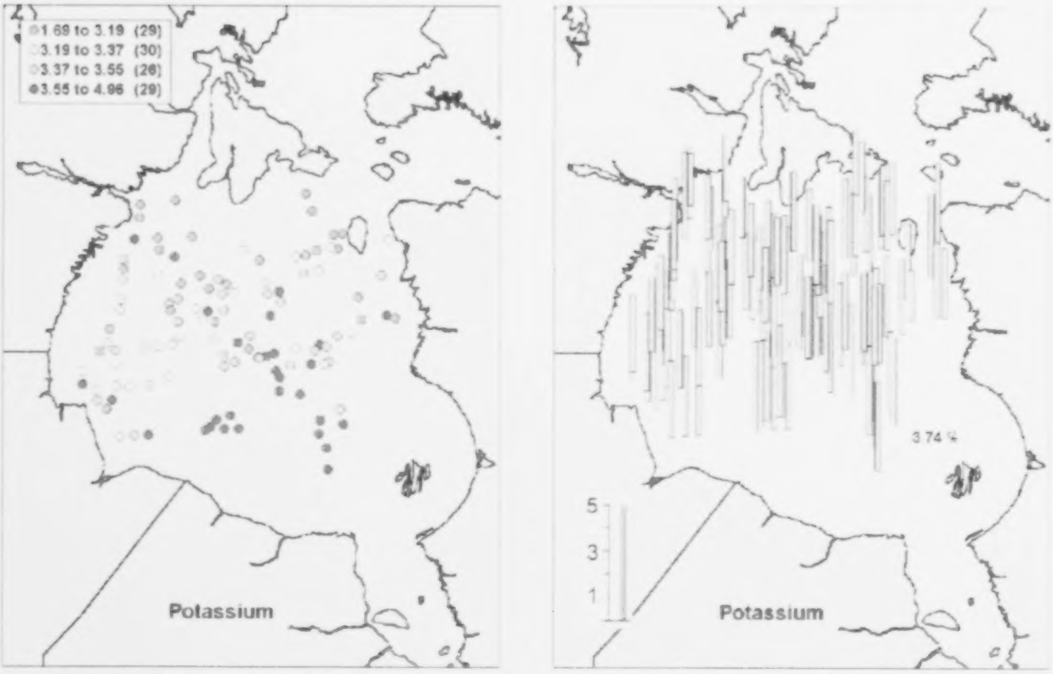


Figure 16-18. Potassium (per cent dry wt.) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to the concentration of potassium (right).

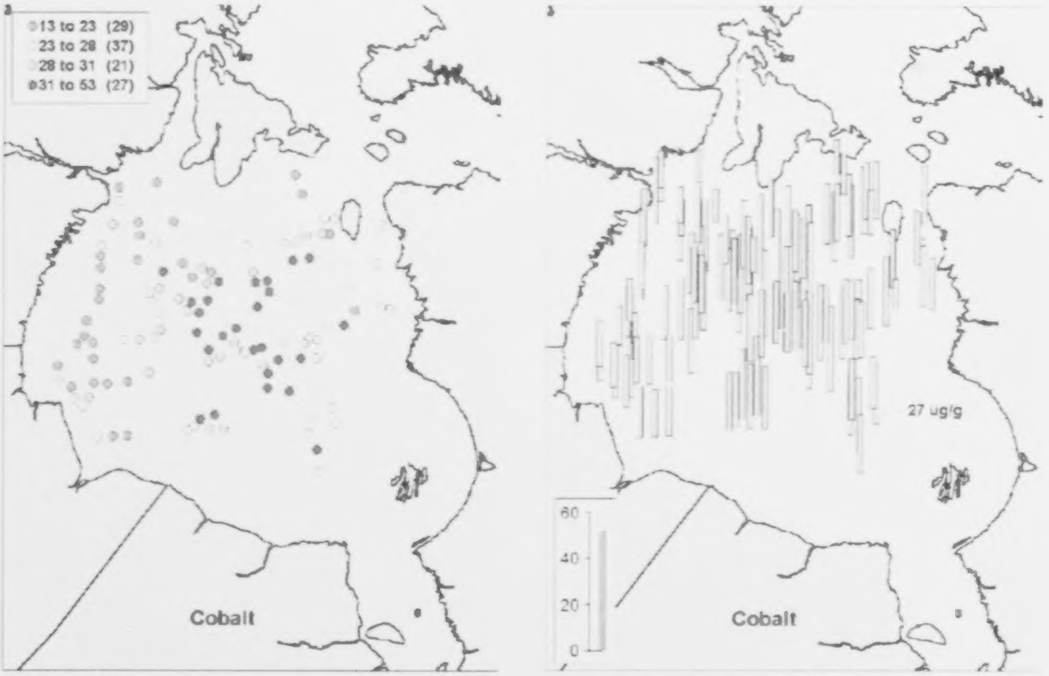


Figure 16-19. Cobalt ($\mu g \cdot g^{-1}$ dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to concentration of cobalt (right).

16.10.2 Manganese

Manganese (Mn) in clay-size particles averaged 0.12 per cent with a very broad range from 0.04 to 1.0 per cent. The highest value was about 25 times the lowest value (Table 16-5). The map in Figure 16-20 (left panel) shows the high values in the central part of Hudson Bay but the bar graphs in Figure 16-20 (right panel) show this cluster more strikingly. Manganese, like cobalt, correlates positively with water depth. Manganese correlates strongly with cobalt, molybdenum and nickel and weakly with potassium and iron (Appendix 7). The cluster of high values in the central region probably implies that conditions there favour diagenesis of manganese. Manganese probably becomes concentrated in surficial sediment there by migration upward from deeper layers in response to chemical and oxidation/reduction gradients. Manganese averaged 0.035 per cent (range 0.022 – 0.062 per cent) in the sediments from the five Ontario rivers reported by McCrea et al. (1984) and so it seems unlikely that manganese originating from these rivers would make a measurable difference in the higher marine values.

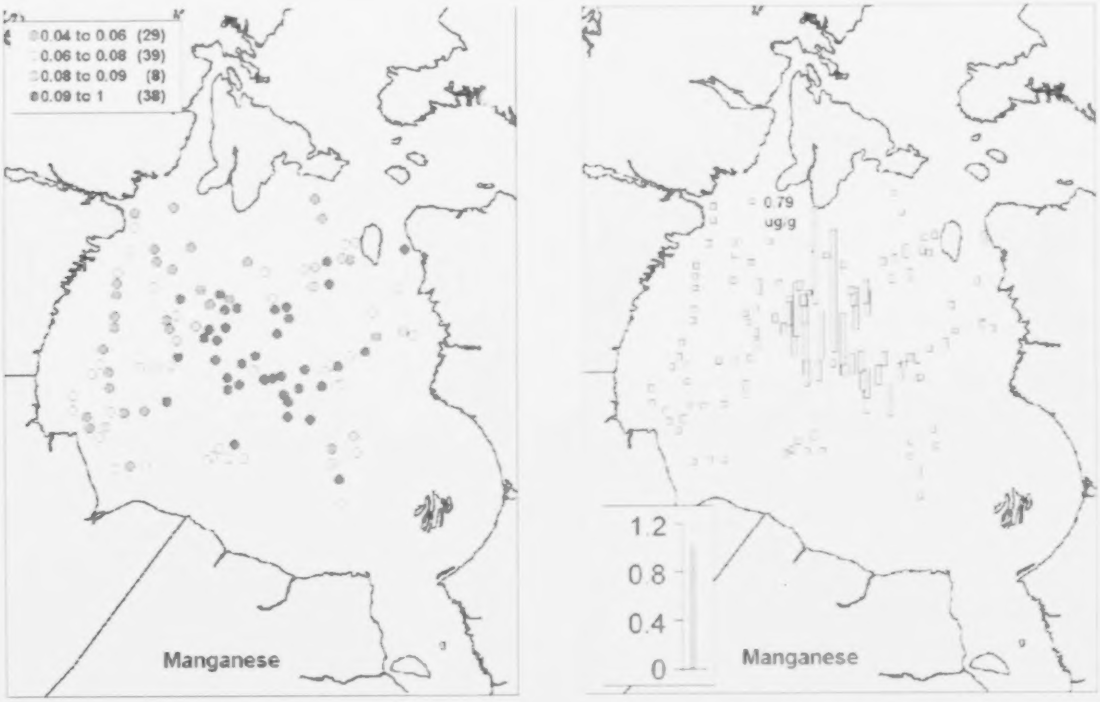


Figure 16-20. Manganese (percent dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to concentration of manganese (right).

16.10.3 Molybdenum

Molybdenum (Mo) in clay-size particles had a relatively narrow range from 0.5 to 12 $\mu g \cdot g^{-1}$ with a mean of 3.37 $\mu g \cdot g^{-1}$ (Table 16-5). The high concentrations were mostly in the central area of Hudson Bay although they differed only slightly from the low values (Figure 16-21, left panel). The bar graphs in Figure 16-21 (right panel) show the relative spatial distribution of molybdenum levels. Molybdenum levels correlated with cobalt, manganese, and nickel but not with water depth (Appendix 7).

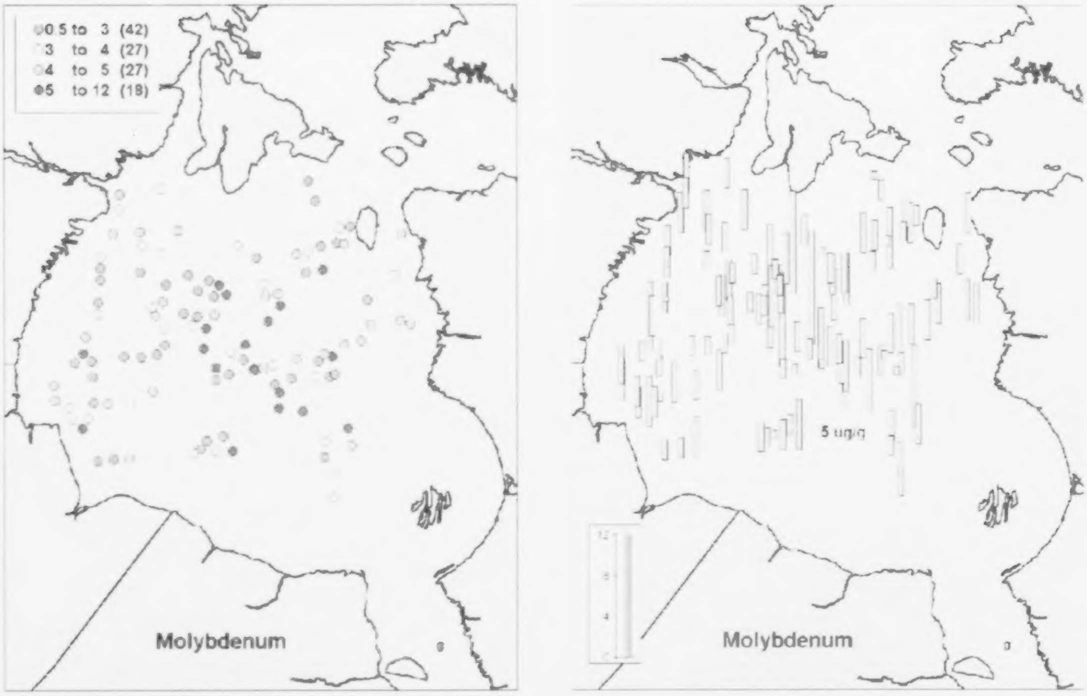


Figure 16-21. Molybdenum (µg·g^{-1} dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to concentration of molybdenum.

16.10.4 Nickel

Nickel (Ni) levels in clay-size particles had a similarly narrow range also, about two-fold from 51 to 107 µg·g^{-1} with a mean of 74 µg·g^{-1}. In view of the small range in values for nickel, the coloured dots in Figure 16-22 (left panel) give a somewhat artificial impression of higher values in the central region. The bar graphs in Figure 16-22 (right panel) give a more realistic impression of relatively uniform levels throughout Hudson Bay. Nickel levels correlated with a number of other metals, notably with chromium (Appendix 7). Nickel levels were lower in the Ontario river sediments reported by McCrea et al. (1984). River sediments ranged from 'not detected' to 24 µg·g^{-1}, with a mean for the 16 positive results of 16 µg·g^{-1}. Painter et al. (1994) provided a map showing the distribution of nickel in lake and stream sediments (Figure 16-23) with areas of high values in the greenstone area around Foxe Basin on Baffin Island and the Melville Peninsula.

16.11 MERCURY

Henderson (1989) did not analyze the Geological Survey samples for mercury. The concentrations of mercury in northern animals with mercury are problematic. Mercury is present naturally in the environment of Hudson Bay but mercury is also added to Hudson Bay by a number of human activities. We have a few core profiles for mercury from southeastern Hudson Bay and also a few dredge samples from the vicinity of Rankin Inlet. Figure 16-24 shows the locations where cores were obtained, and the down-core profiles of mercury in three sediment cores from southeastern Hudson Bay. The ISQG for mercury in marine sediment is 0.13 µg·g^{-1} and the PEL for mercury is 0.7 µg·g^{-1}. Mercury levels in the cores range from 0.013 to 0.037 µg·g^{-1} (Figure 16-24). These samples were not fractionated before analyses and so the concentrations found are directly comparable to ISQG and PEL figures. This comparison suggests that levels of mercury in surficial sediments of southeastern Hudson Bay are well below ISQG and PEL values. Core Hud-4 was taken near the Great Whale River and any inputs

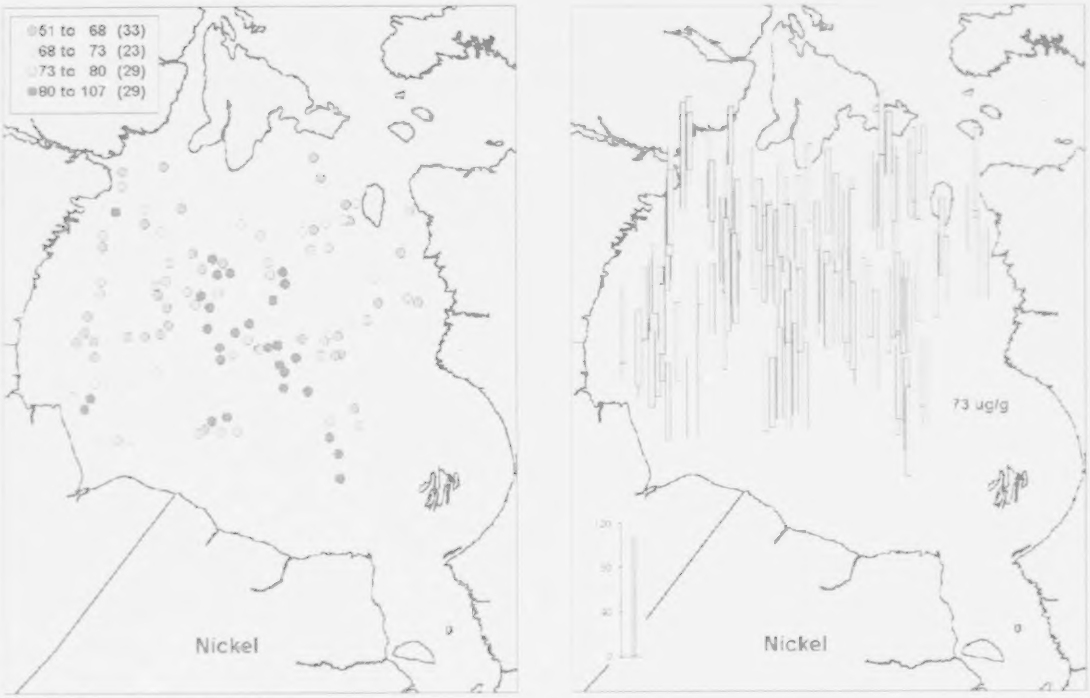


Figure 16-22. Nickel (μg·g^{-1} dry weight) in clay-size particles of surficial sediment from Hudson Bay. Data from Henderson (1989). Ranges selected to place approximately equal numbers of points in each range (left); same data shown as bars with bar height scaled to the concentration of nickel (right).

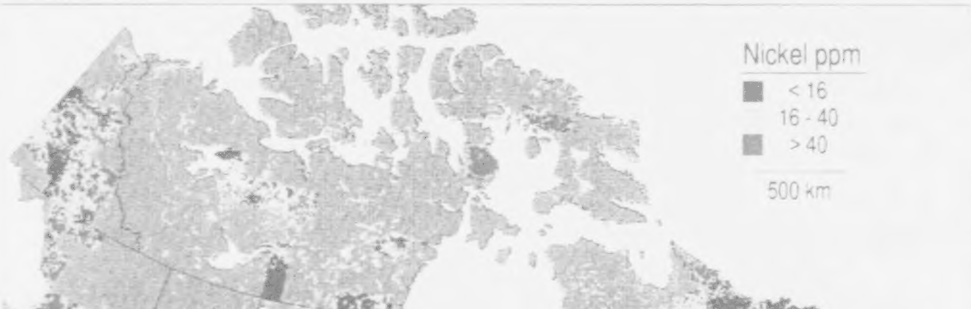
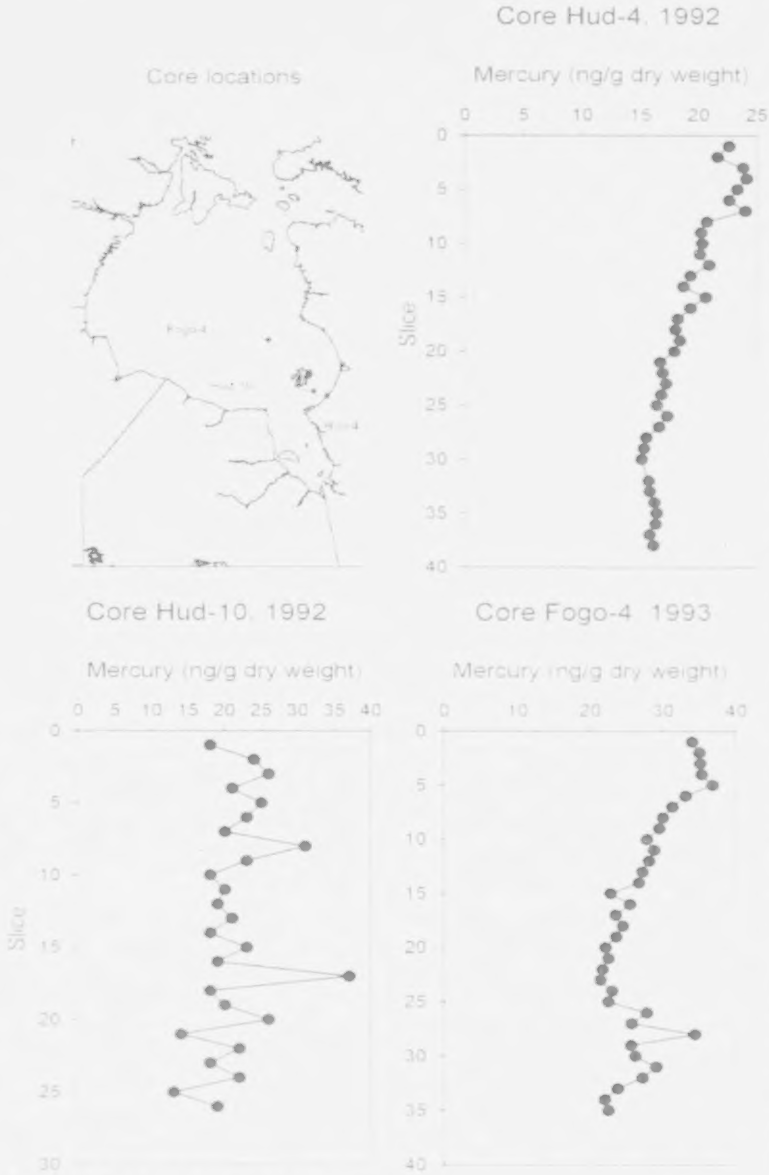


Figure 16-23. Nickel in lake and stream sediment samples (from Painter et al. 1994, page 223).



Core locations

Core Hud-4, 1992

Core Hud-10, 1992

Core Fogo-4, 1993

Figure 16-24. **Locations of three sediment cores from Hudson Bay in 1992 and 1993 and down-core profiles of mercury ($ng \cdot g^{-1}$ dry weight). (L. Lockhart, unpublished data).**

from the river have not been sufficient to bring the concentration up to the ISQG. In addition to the cores from southeastern Hudson Bay, several VanVeen dredge samples taken from near Rankin Inlet in 1995 contained mercury at levels up to 0.014 $\mu g \cdot g^{-1}$, also well below ISQG and PEL values.

Painter et al. (1994) presented data on mercury in 161,228 samples of lake and stream sediment. The median level was 0.06 $\mu g \cdot g^{-1}$ with the 95th percentile at 0.19 $\mu g \cdot g^{-1}$. Most samples (about 70 per cent) were below the ISQG for mercury. Most of the samples were not from Hudson Bay/Foxe Basin drainages, but those that were often fell below 50 $ng \cdot g^{-1}$, with some in the 50-100 $ng \cdot g^{-1}$ range, and with only a few exceeding 100 $ng \cdot g^{-1}$ (Figure 16-25). Taking these lake and stream sediment data together with the few data we have from Hudson Bay, it appears that Hudson Bay sediments are depleted in mercury relative to many others. The concentrations of mercury in samples we have of Hudson Bay sediment do not portray a problem with mercury. The river sediment samples reported by McCrea et al. (1984) were all given as either 0.01 or 0.02 $\mu g \cdot g^{-1}$ or as 'not detected.' In spite of the low levels of mercury in the sediments, there is a persistent problem with accumulations of mercury in marine animals high in the food chains. Two guideline figures are used in efforts to limit human intake of mercury. Concentrations should not exceed 0.5 $\mu g \cdot g^{-1}$ (wet weight) in fish sold commercially in Canada, and levels should not exceed 0.2 $\mu g \cdot g^{-1}$ (wet weight) in fish used for subsistence consumption (Health and Welfare Canada 1979). Levels of mercury in some organs of seals and whales, for example, frequently exceed those levels.

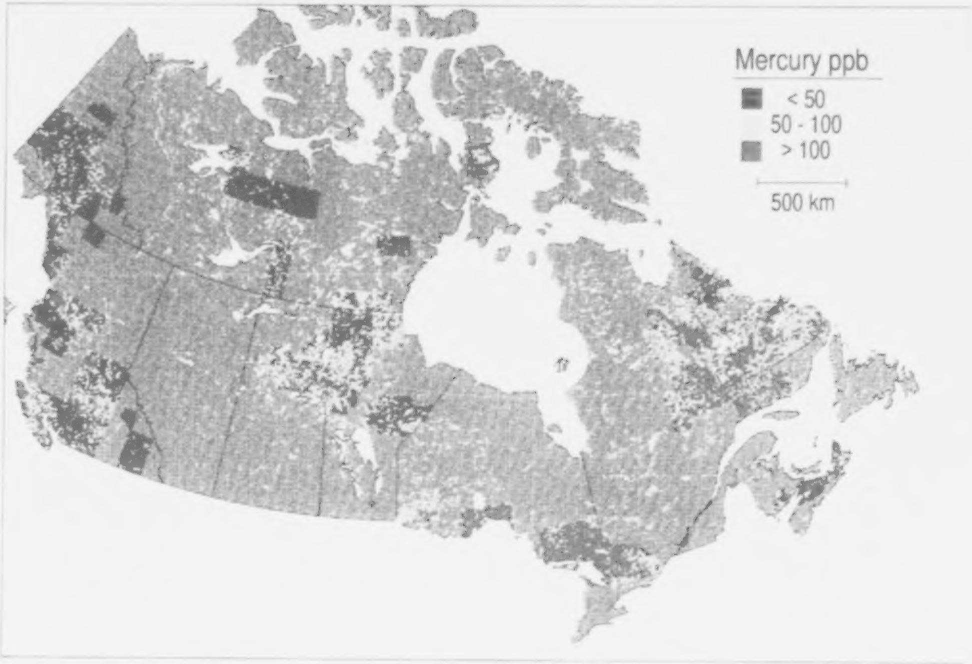


Figure 16-25. Mercury in lake and stream sediment samples (from Painter et al. 1994, page 226).

16.11.1 Mercury in the biota of Hudson Bay

When considering contaminants in animals, especially animals that range over large geographic areas, data on exact positions where animals were taken are of limited value. Rather than organize data by geographic coordinates, locations where samples were collected are generally identified as a nearby community or geographic feature. For example, samples may be identified as Sanikiluaq or Belcher Islands, with no information available on exactly where the samples were obtained.

We have a few scattered data on levels of mercury in benthic marine animals. For example, Table 16-7 and Table 16-8 list unpublished levels of mercury found in some benthic animals collected from C.S.S. Hudson in 1992 and 1996. The samples were collected in southeastern Hudson Bay in 1992 and in the vicinity of Rankin Inlet in 1996. The collection in 1992 was made by freezing specimens on the ship so that the taxonomist (P.L. Wong) worked from frozen material (Table 16-7). This was not satisfactory for some groups, especially the polychaetes, so that the animals collected in 1996 were examined freshly on board the ship by the taxonomist (M. Curtis, Table 16-8). The concentrations are expressed on a dry weight basis and so they are not readily compared with the human consumption guidelines that are expressed on a wet weight basis. As a crude guideline, the dry weight may be about 20-25 per cent of the total wet weight, and so the mercury level on a wet weight basis would be about one quarter of the concentrations shown in Table 16-7 and Table 16-8. Atwell et al. (1998) reported levels of mercury in several invertebrate species from Lancaster Sound and their values were generally lower than those we obtained for the benthic animals from Hudson Bay. For example, Atwell et al. (1998) obtained 0.09 $\mu g \cdot g^{-1}$ (dry weight) of mercury in a specimen of *Macoma calcarea* and we obtained an average of 0.22 $\mu g \cdot g^{-1}$ for six specimens of the same species (Table 16-8).

Surprisingly perhaps, the recent CACAR II (2003: Biological Environment) compendium lists no data on mercury in marine fish from Hudson Bay. Three fourhorn sculpins (*Myoxocephalus quadricornis*) were taken in August, 1992, and found to have mercury levels in muscle of 0.10, 0.27 and 0.21 $\mu g \cdot g^{-1}$ wet weight (L. Lockhart, unpublished data). Schetagne and Verdon (1999) reported mercury in fourhorn sculpins from several stations

Table 16-7. **Mercury (μg·g^{-1} dry weight) in benthic animals taken in box cores and VanVeen sediment dredges from southeastern Hudson Bay, August, 1992. (L. Lockhart, unpublished data).**

Species	n	Minimum (μg·g^{-1} dry weight)	Maximum (μg·g^{-1} dry weight)	Mean (μg·g^{-1} dry weight)
Bivalve, *Nucula belloti*	10	0.132	0.846	0.345
Bivalve, *Thyasira gouldi*	10	0.164	1.787	0.719
Bivalve, *Yoldiella lenticula*	5	0.423	1.450	0.784
Bivalve, *Portlandia arctica*	4	0.149	0.421	0.249
Bivalve, *Periploma absyssorum*	3	0.110	0.849	0.477
Bivalve, *Nuculana penula*	pooled			0.388
Brittle stars (unclassified)	pooled			0.045
Polychaetes (unclassified)	15	0.014	0.285	0.100
Starfish (unclassified)	8	0.015	0.100	0.057
Sea urchins (unclassified)	8	0.004	0.030	0.017
Star lillies (unclassified)	3	0.040	0.048	0.043

Animal taxonomic identifications by P.L. Wong, DFO, Winnipeg.

Table 16-8. **Mercury (μg·g^{-1} dry weight) in benthic animals taken in VanVeen sediment dredges from Hudson Bay near Rankin Inlet, August, 1996. (L. Lockhart, unpublished data).**

Species	n	Minimum (μg·g^{-1} dry weight)	Maximum (μg·g^{-1} dry weight)	Mean (μg·g^{-1} dry weight)
Amphipod, *Ampelisca eschrichti*	15	0.025	0.048	0.035
Brittle star, *Stegophiura nodosa*	1			0.048
Bivalve, *Astarte crenata*	23	0.075	0.186	0.135
Bivalve, *Serripes groenlandicus*	7	0.067	0.179	0.122
Bivalve 1, *Macoma* spp	11	0.092	0.198	0.148
Bivalve 2, *Macoma* spp	4	0.109	0.601	0.244
Bivalve 3, *Mya pseudoarenaria*	9	0.073	0.14	0.105
Bivalve 4, *Macoma calcarea*	6	0.181	0.331	0.219
Bivalve 5, *Nucula belloti*	12	0.101	0.552	0.305
Bivalve 6, *Yoldia hyperborea*	7	0.144	0.722	0.368
Bivalve 7, *Clinocardium ciliatum*	18	0.130	0.392	0.247
Bivalve 8, *Nuculana pernula*	5	0.172	0.240	0.202
Polychaete, *Ophelia limacina*	1			0.044
Polychaete, *Praxillela gracilis*	1			0.075
Polychaete, *Ammotrypane cylindricaudatus*	6	0.14	0.209	0.168
Polychaete, *Maldane sarsi* (large)	2	0.178	0.197	0.188
Polychaete, *Nephtys*	7	0.094	0.262	0.136
Polychaete, *Lumbrineris*	12	0.068	0.228	0.126
Slender eelblenny, *Lumpenus fabricii*	1			0.080

Animal taxonomic identifications by M. Curtis, DFO, Winnipeg.

along the James Bay coast; station means ranged from 0.10 to 0.55 μg·g^{-1} wet weight for sculpins of standardized 250-mm length. Similarly, greenland cod (*Gadus ogac*) from the same stations on eastern James Bay had station means values from 0.14 to 0.42 μg·g^{-1} wet weight for cod 400 mm in length. The stations on the James Bay coast were part of a large study of mercury in fish from habitats affected by hydroelectric developments in Quebec. The authors reported effects of the La Grande complex of dams and reservoirs extended downstream, but that effects were limited to a relatively small area influenced by the summer freshwater plume from the river. Hydro Quebec (Hayeur 2001) mentioned that the area of influence extends 10-15 km on each side of the mouth of the river. Some station means for fourhorn sculpin and greenland cod from eastern James Bay included values that exceed the guideline value of 0.2 μg·g^{-1} (wet weight) for subsistence consumption but it is not clear whether hydroelectric facilities were responsible.

The CACAR II (2003: Biological Environment, Annex Table 5) lists concentrations of mercury in muscle of anadromous Arctic charr from a number of locations in northern Quebec and Labrador including one on the east side of Hudson Bay. Mean values ranged from 0.027 to 0.072 μg·g^{-1} (wet weight), all well below the guidelines for human consumption and also below the figures for sculpins and greenland cod noted above. These values for Arctic charr are shown in Figure 16-26. Included in the figure is one collection of landlocked charr from Kangiqsujuag and those charr were about three-fold higher in mercury content than the anadromous charr from the same area. Similar data on the bivalve Mytilus edulis (whole body) had a range from 0.01 to 0.03 μg·g^{-1} wet weight. The CACAR II table also listed cadmium, arsenic, selenium and lead for most of the collections of charr and mussels. The earlier CACAR I (1997: page 206, Table 3.3.5) report gave levels of mercury in muscle of several species of fish from the Grande Baleine River: lake trout, 0.71 μg·g^{-1}; lake whitefish, 0.14 μg·g^{-1}; and northern pike, 0.63 μg·g^{-1}. Lake trout and northern pike exceeded human consumption guidelines. However, lake trout from the Rankin Inlet-Arviat area of western Hudson Bay had considerably lower levels, 0.064 μg·g^{-1}. Other lakes (Hawk Lake, Peter Lake) also in the area of western Hudson Bay had mean levels of 0.24 and 0.67 μg·g^{-1}.

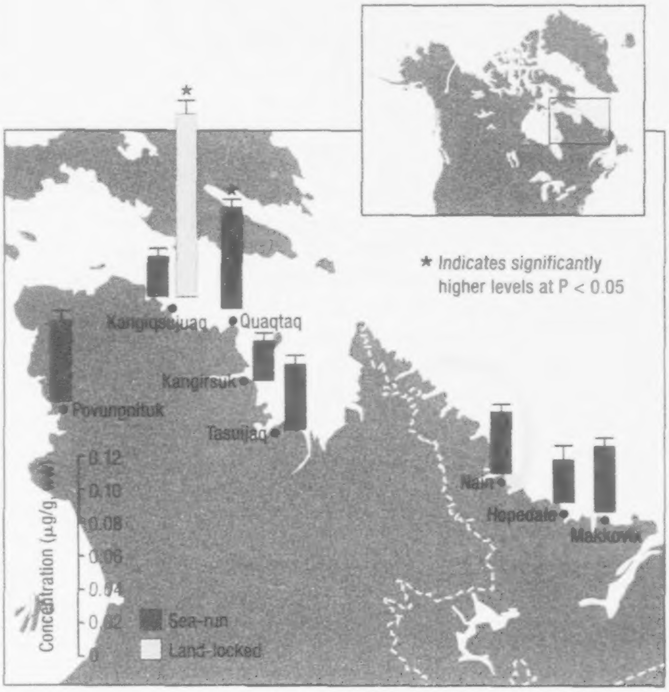


Figure 16-26. Mercury concentrations (μg·g^{-1} wet weight) in muscle of anadromous and landlocked Arctic charr from Nunavik and Labrador (1998-1999). Mercury concentrations have been adjusted for age and length of fish. (From CACAR II 2003: Biological Environment, Figure 3.3.2, page 29).

Mercury levels in some of the landlocked predatory fish like lake trout are relatively high; however, those in anadromous charr are considerably lower, implying that feeding at sea supplies less mercury than feeding in lakes. So little is known about levels in fully marine fish of Hudson Bay, that the few scattered reports available do little more than establish the need for a systematic survey of levels of mercury in marine fish and their supporting food chains. Such a survey would also help isolate the real and potential contributions of freshwater sources such as hydroelectricity projects and possibly regional climate warming in western Hudson Bay watersheds.

There have been several studies of mercury in northern birds and these have often included collections from Hudson Bay. For example, Figure 16-27, taken from CACAR II (2003) shows the levels of mercury in liver of eider ducks from two locations in Hudson Bay and from Holman Island in the western Arctic. The common eiders contained mercury in liver at concentrations in the 0.4 to 0.51 µg·g^{-1} wet weight range with little difference among geographic areas. Mercury in king eiders was slightly higher. Seals and whales from the western Arctic generally contain higher levels of mercury than those from Hudson Bay, but this is not the case with eiders. One potential explanation for the low levels in the eiders from Holman may be that the levels reflect wintering areas in the northern Bering Sea, Bering Strait, and southern Chuckchi Sea. The apparent difference between common eiders and king eiders may be related to their diets. Both species eat mussels, but common eiders are more specialized feeders while king eiders eat a varied diet including echinoderms and other invertebrates. Figure 16-28 shows similar data for long-tailed ducks (oldsquaw). The levels of mercury in liver are considerably lower than those in eiders and they vary more widely among sites. Long-tailed ducks (oldsquaw) from Sanikiluaq had the lowest levels among the collections from marine areas.

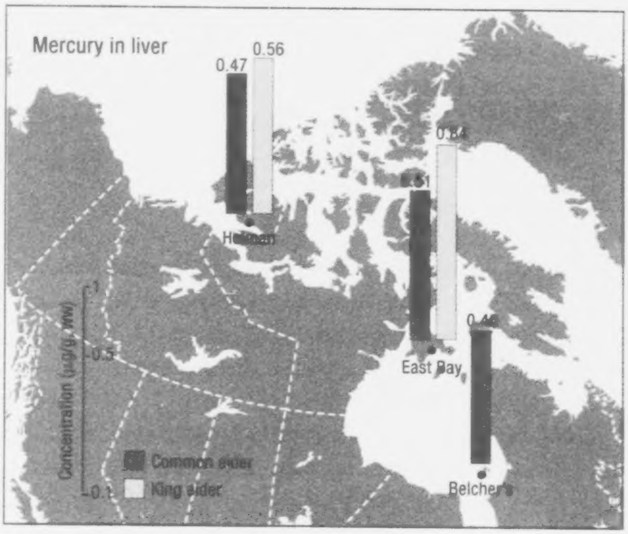


Figure 16-27. **Mercury (geometric means in µg·g^{-1} wet weight) in liver of common eiders and king eiders from two locations in Hudson Bay and from Holman in the western Arctic. (From CACAR II 2003: Biological Environment, Figure 3.2.2, page 25).**

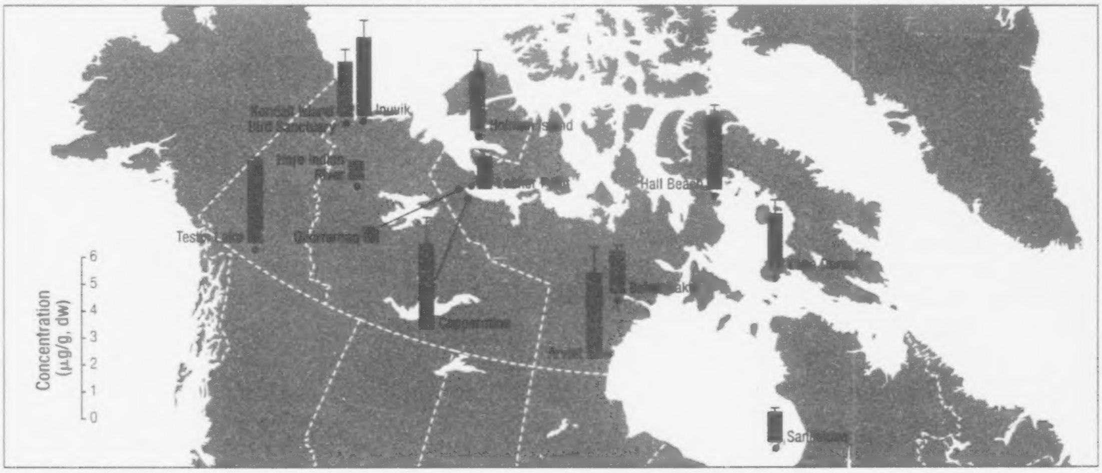


Figure 16-28. **Total mercury (µg·g^{-1} dry weight) in liver of long-tailed ducks collected between 1991 and 1994. (From CACAR II 2003: Biological Environment, Figure 3.3.6, page 34).**

Mercury levels have increased since the 1970s some arctic birds. Figure 16-29 shows graphs of temporal trends in eggs of three species from Prince Leopold Island, northern fulmar, black-legged kittiwake, and thick-along the James Bay coast; station means ranged from 0.10 to 0.55 $\mu g \cdot g^{-1}$ wet weight for sculpins of standardized 250-mm length. Similarly, greenland cod (*Gadus ogac*) from the same stations on eastern James Bay had station means values from 0.14 to 0.42 $\mu g \cdot g^{-1}$ wet weight for cod 400 mm in length. The stations on the James Bay coast were part of a large study of mercury in fish from habitats affected by hydroelectric developments in Quebec. The authors reported effects of the La Grande complex of dams and reservoirs extended downstream, but that effects were limited to a relatively small area influenced by the summer freshwater plume from the river. Hydro Quebec (Hayeur 2001) mentioned that the area of influence extends 10-15 km on each side of the mouth of the river. Some station means for fourhorn sculpin and greenland cod from eastern James Bay included values that exceed the guideline value of 0.2 $\mu g \cdot g^{-1}$ (wet weight) for subsistence consumption but it is not clear whether hydroelectric facilities were responsible.

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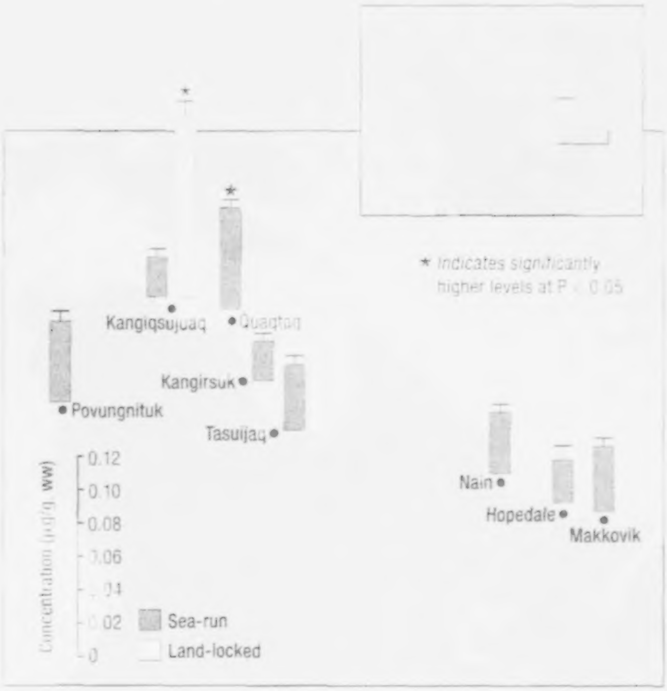

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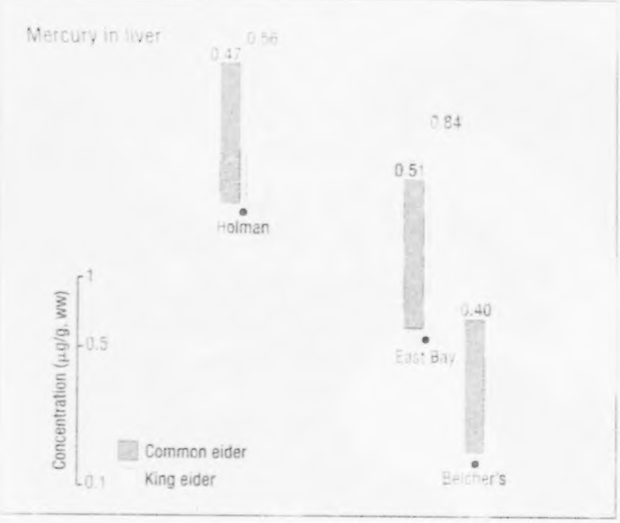

Figure 16-27 Mercury (geometric means in µg·g^{-1} wet weight) in liver of common eiders and king eiders from two locations in Hudson Bay and from Holman in the western Arctic. (From CACAR II 2003: Biological Environment, Figure 3.2.2, page 25).

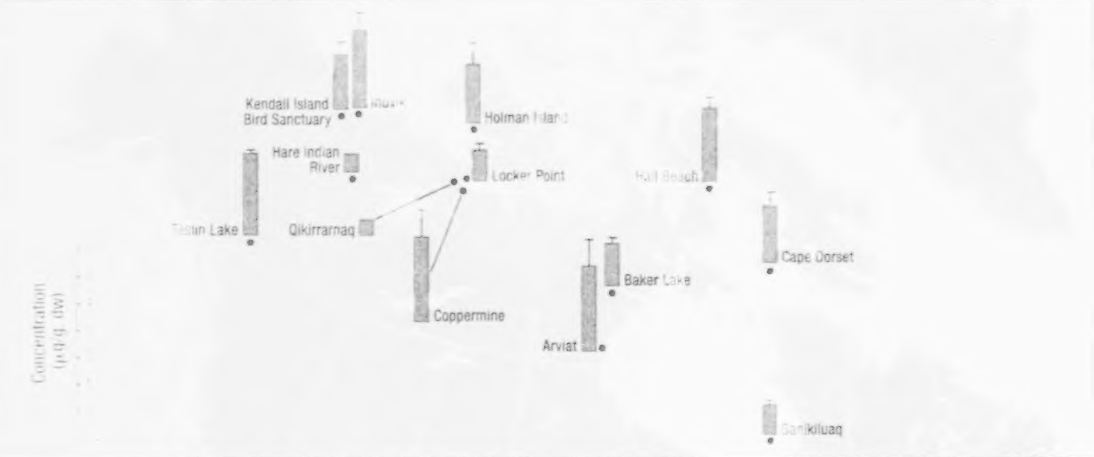

Figure 16-28. Total mercury (µg·g^{-1} dry weight) in liver of long-tailed ducks collected between 1991 and 1994. (From CACAR II 2003: Biological Environment, Figure 3.3.6, page 34).

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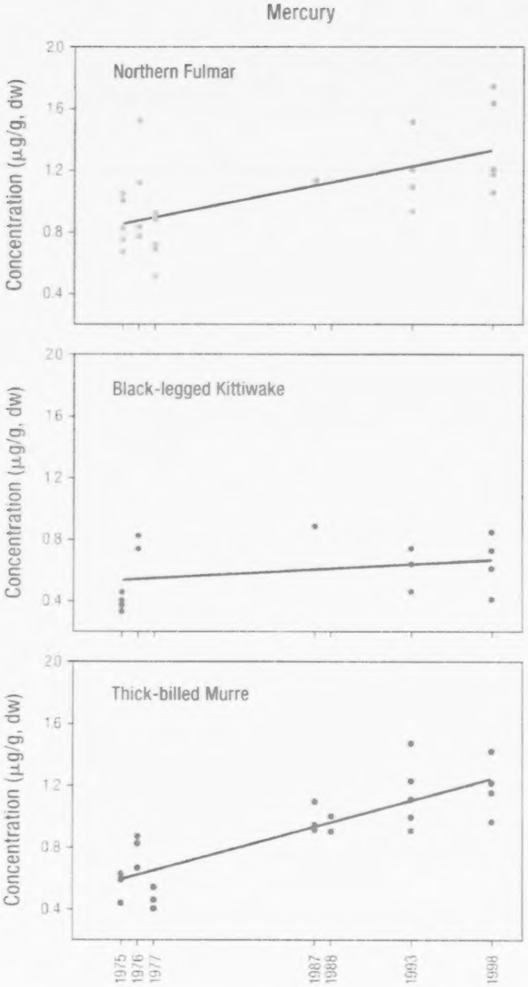

Figure 16-29. **Mercury in eggs of three species of sea birds from Prince Leopold Island between 1975 and 1998. (From CACAR II 2003: Biological Environment, Figure 4.2.3, page 70).**

Of all northern animals, marine mammals generally have the highest levels of mercury. Most chemical residue analyses have been done with ringed seals, beluga whales and polar bears. Figure 16-30 shows concentrations of mercury, arsenic, cadmium, and lead in liver of ringed seals from a number of locations including one in Hudson Bay. The age-adjusted levels of mercury appear to be higher in the seals from Arviat than from other locations but the high statistical variance in the data means that the apparent difference was not meaningful. The levels in liver are very high in

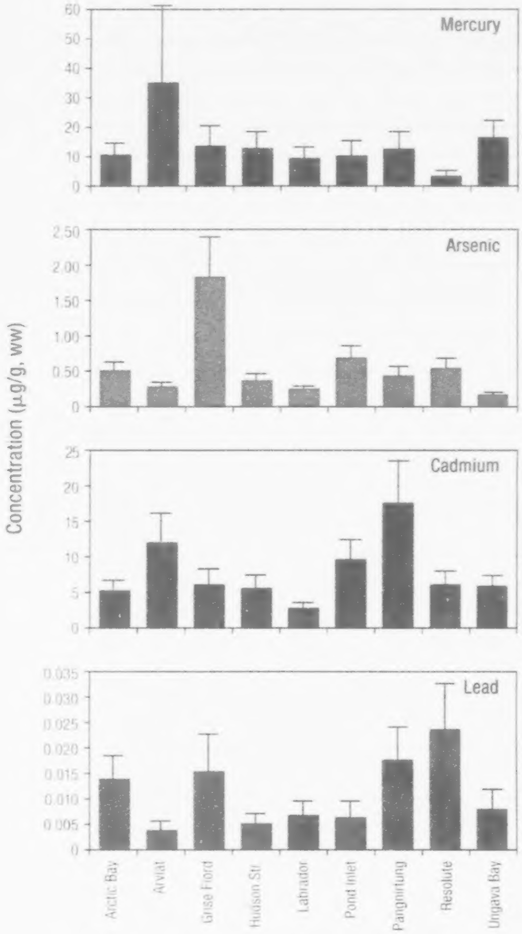

Figure 16-30. **Mercury, arsenic, cadmium and lead concentrations (µg·g^{-1} wet weight) in liver of ringed seal from nine locations in the eastern/central Canadian Arctic. Results are based on seals from age 2-15 years. Mercury concentrations are adjusted for age. (From CACAR II 2003: Biological Environment, Figure 3.3.1.1, page 39).**

comparison with the human consumption guidelines for fish (0. 5 µg·g^{-1} wet weight for commercial sale) but the biochemical form assumed by mercury in seal liver is different from that in fish muscle. In fish, most of the mercury is present as the neurotoxic form, methylmercury, but in seals and beluga whales the form of mercury varies from organ to organ. Methylmercury comprises only a small proportion of the total mercury in the liver of ringed seals (Wagemann et al. 2000). CACAR II (2003, page 99) reports that the threshold concentration for liver damage in marine mammals is 60 µg·g^{-1}. Figure 16-30 indicates that the average concentration of mercury in liver of seals from Arviat was about 34 µg·g^{-1} with an error bar extending over 60 µg·g^{-1} and so some seals in Hudson Bay may have liver concentrations of mercury high enough to result in biological harm.

Beluga whale liver also contains high levels of mercury but, again, only a small proportion of it is present as methylmercury. There appears to be some variation in mercury levels among beluga from different regions. Figure 16-31 shows mean levels of total mercury in liver of beluga (adjusted for age) from locations where multiple collections have been made over the period from 1981 to 2002. The whales from the Beaufort Sea coast generally had higher levels than those from any of the locations in Hudson Bay. Mercury levels seem to have increased since the mid- 1980s in several of the collections. Statistically, the apparent increase is evident at Arviat where the two collections were separated by 15 years. The collection in 1999 had concentrations of mercury more than twice as high as those in the collection in 1984. There was no apparent trend in whales from Coral Harbour but the first collection was in 1993. There appears to have been an increase also at Sanikiluaq but the collections there were only four years apart and no trend can be established rigorously. The same can be said of the whales from Iqaluit where the collections were only one year apart, although the figures give the appearance of an increase in levels. The samples from Pangnirtung do show an apparent increase since the first collection in 1984. The whales taken at Arviat summer downstream from the Churchill-Nelson hydroelectricity development but the other whales analyzed to date would not be expected to summer near any hydroelectricity development. CACAR II (2003) reported that the threshold for biological effects in marine mammals was 60 µg·g^{-1} and some 32 beluga liver samples exceeded that value of the 528 for which we have data. If this threshold is applied to beluga, then some beluga contain sufficient mercury in liver that it should pose a toxicity risk to them.

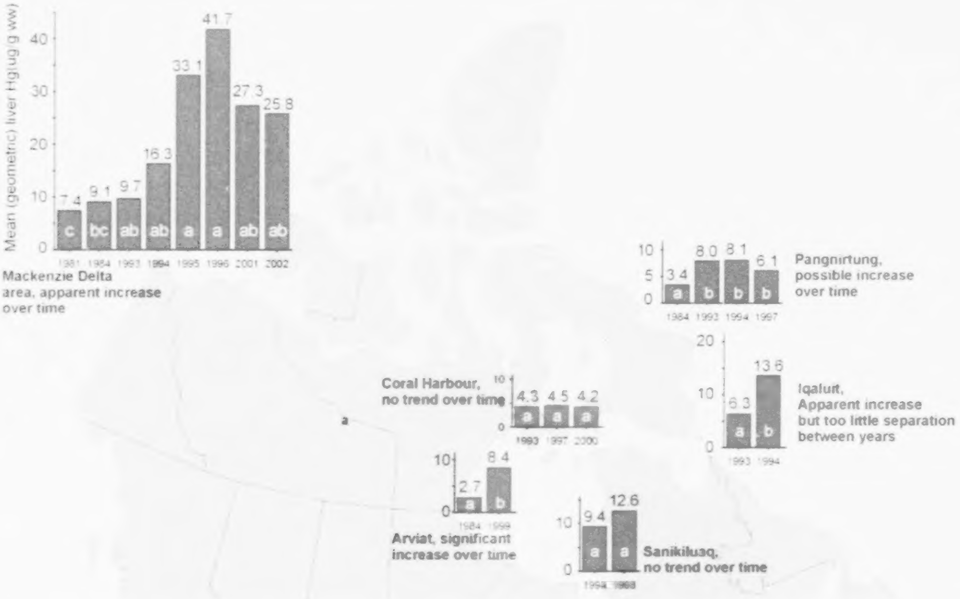

Figure 16-31. **Mean concentrations of total mercury (µg·g^{-1} wet weight, adjusted for whale age) in liver of beluga whales from several sites in northern Canada from 1981 to 2002 (Figure modified from Lockhart et al., presented at Northern Contaminants Program symposium, Ottawa). Figures at the bases of the bars are years when samples were obtained; figures at the tops of the bars are least square geometric means; letters on the bars indicate statistical differences by Duncan's test.**

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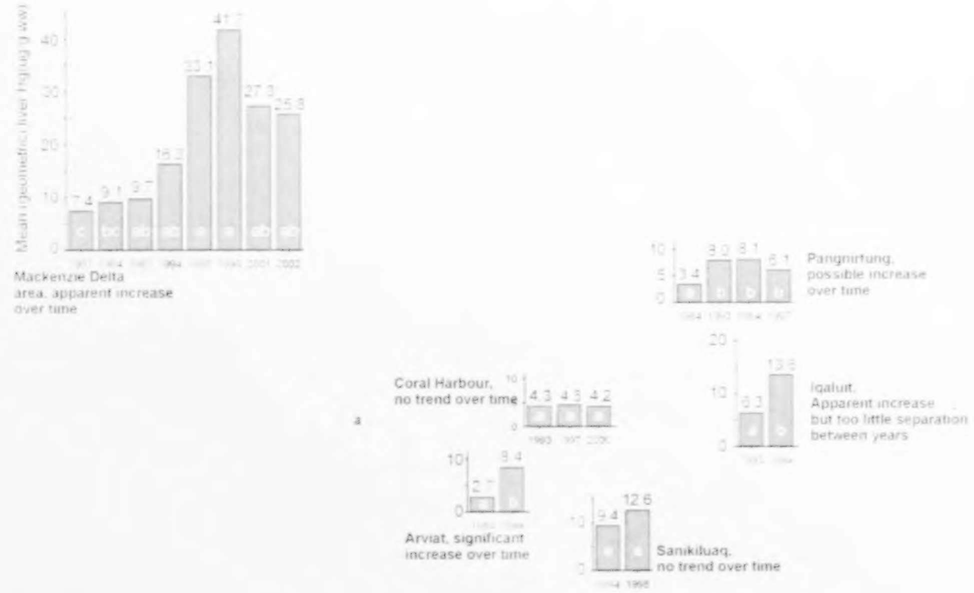

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The levels of mercury in the whales vary greatly among different organs. Figure 16-32 shows the levels of mercury and selenium in different organs of beluga from the Mackenzie Delta. Although these whales were not from Hudson Bay, it seems unlikely that the beluga from Hudson Bay would process and store mercury very differently from other beluga. Mercury concentrations were considerably higher in liver than in other organs with kidney and brain having the next highest levels. Mercury was lowest in urine, milk, heart, and lung. Two organs separated clearly from the others, namely muscle with relatively low selenium for its level of mercury, and muktuk with high selenium for its level of mercury (Figure 16-32). The relationship between mercury and selenium may be important because several studies have shown that the presence of selenium can ameliorate the toxicity of mercury. For example, Eaton et al. (1981) reported that cats given selenium with mercury did not develop the symptoms of mercury poisoning found in cats given the same amount of mercury without the accompanying selenium.

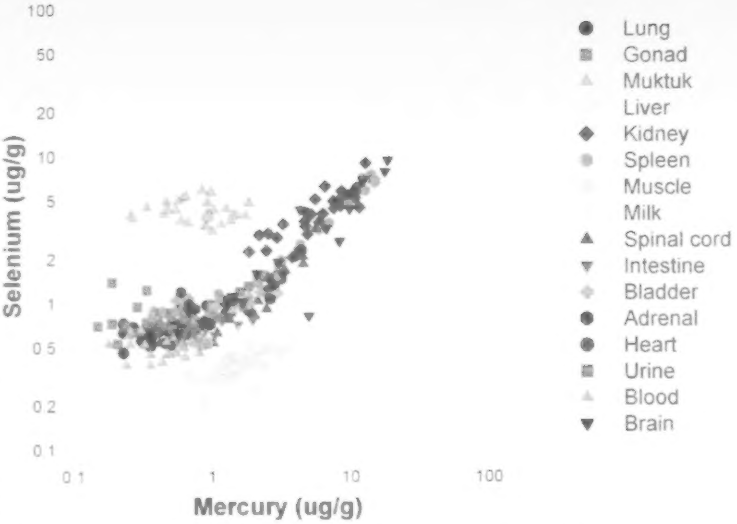

Figure 16-32. Total mercury and selenium (μg·g^{-1} wet weight) in organs of beluga whales from the Mackenzie Delta area. (From Hyatt et al. 1999).

The high level of mercury in liver has been fractionated into several different forms of mercury. Figure 16-33 shows a pie chart indicating the proportions found in each different form. Only about 6 per cent of the total mercury in these samples was present as the neurotoxic methylmercury. The speciation varies strikingly from one organ to another. For example, in one study the proportion of methylmercury in beluga muscle from the eastern Arctic was 93 % while that in liver from the same animals it was only 11.7 % (Wagemann et al. 1998). The major form is thought to be mercury selenide, an inert form that is found naturally as the mineral tiemannite, HgSe. Since the whales major intake of mercury is from dietary methylmercury, the presence of a high proportion of HgSe in the liver may represent a metabolic detoxification mechanism to bind the mercury as an inert form and render it non-toxic or at least less toxic. The speciation of mercury appears also to differ geographically. The proportion of total liver mercury represented by methylmercury was 11.7 % in the eastern Arctic, but only 5.9 % in the western Arctic (G.A. Stern et al. 2003 Northern Contaminants Program Synopsis Report for 2001 and 2002, in press).

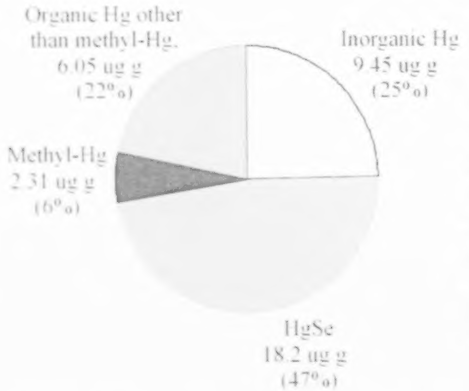

Figure 16-33. Pie chart showing arithmetic mean concentrations (μg·g^{-1} wet weight; with percentages in parentheses) of biochemical forms of mercury in liver of beluga whales. (From Lockhart et al. 1999).

Considering seals and whales together, our most comprehensive set of analyses is on liver. The most recent tabulation of DFO data on levels of mercury in liver from animals in or around Hudson Bay is shown in Table 16-9 (without statistical corrections for ages of the animals). With the exception of the two bowhead whales, all samples exceeded the human consumption guideline (0.05 μg·g^{-1} wet weight in commercial fish) for mercury.

Table 16-9. Ages and levels of mercury, selenium and cadmium (μg·g^{-1} wet weight) in liver of bowhead whales, ringed seals, beluga, narwhal and walrus taken from locations in or around Hudson Bay. (n=number of samples for which a measurement was made).

Species	Location	Year	Age (y)		Total Hg (μg·g^{-1} ww)			Se (μg·g^{-1} ww)			Cd (μg·g^{-1} ww)		
			n	mean	n	mean	S.D.	n	mean	S.D.	n	mean	S.D.
Beluga	Arviat	1984	22	11.2	23	6.62	6.94	23	4.16	2.40	23	6.73	6.69
Beluga	Arviat	1999	37	11.2	37	12.68	9.93	37	8.47	6.77	37	11.9	6.72
Beluga	Coral Harbour	1993	11	16.1	11	6.54	2.97	11	3.99	2.27	11	8.98	5.22
Beluga	Coral Harbour	1997	19	13.1	20	13.38	28.6	20	9.08	15.3	20	8.35	3.78
Beluga	Coral Harbour	2000	24	8.9	25	3.95	2.48	25	4.23	2.51	25	9.22	5.79
Beluga	Igloolik	1995	35	11.5	35	10.59	8.49	35	8.19	3.11	35	6.63	4.05
Beluga	Lake Harbour	1994	19	10.8	20	9.30	6.39	20	7.18	4.04	20	5.48	4.71
Beluga	Lake Harbour	1997	10	16.1	9	11.72	4.17	9	5.92	1.71	9	6.93	3.97
Beluga	Lake Harbour	2001	13	14.1	13	16.42	9.83				13	5.91	2.19
Beluga	Nastapoca	1984	14	13.2	15	10.70	13.7	10	4.60	2.31	15	5.12	2.70
Beluga	Repulse Bay	1993	2	8.0	2	3.43	3.09	2	4.83	2.06	2	9.75	5.20
Beluga	Sanikiluaq	1994	30	13.7	30	12.90	9.53	30	9.76	4.82	30	7.62	3.96
Beluga	Sanikiluaq	1998	22	13.0	22	21.05	25.2	22	16.04	14.9	22	1.32	0.60
Bowhead	Igloolik	1994			1	0.02		1	0.37		1	0.04	
Bowhead	Repulse Bay	1996			1	0.01		1	0.35		1	0.74	
Narwhal	Repulse Bay	1993			4	7.91	6.77	4	5.45	4.35	4	30.7	27.92
Narwhal	Repulse Bay	1999			18	11.39	7.21						
Ringed seal	Arviat	1992	73	13.7	69	22.97	30.0	69	10.91	9.28			
Ringed seal	Arviat	1998	24	18.7	24	21.80	17.2						
Ringed seal	George River		2	6.0	2	11.03	2.37	2	6.81	0.74	2	25.11	25.64
Ringed seal	George River	1989	3	10.0	3	12.90	13.5	3	7.27	5.87	3	6.70	9.13
Ringed seal	George River	1990	2	6.0	2	14.48	10.5	2	5.66	0.02	2	3.44	0.07
Ringed seal	George River	1991	2	8.0	2	4.62	2.47	2	3.12	1.48	2	5.41	4.64
Ringed seal	Inukjuak	1989	2	5.0	2	2.36	2.38	2	3.88	1.95	2	7.80	7.83
Ringed seal	Inukjuak	1990	8	5.3	8	5.56	2.71	8	5.82	1.73	8	17.51	10.34
Ringed seal	Saluit	1989	2	10.0	2	19.17	10.2	2	7.95	1.66	2	10.74	4.91
Ringed seal	Sanikiluaq	1991	27	8.4	26	8.28	6.55	26	6.60	3.36	26	14.26	7.06
Ringed seal	Umiujaq	1994			52	16.43	25.4	52	9.96	7.67			
Ringed seal	Wakeham Bay	1989	23	3.1	23	3.85	5.81	23	3.12	3.06	23	7.74	8.76
Ringed seal	Wakeham Bay	1990	10	6.7	10	6.39	5.88	10	3.91	1.78	10	5.11	7.88
Walrus	Akulivik	1990	4	5.7	4	4.86	0.85	4	3.99	0.57	4	10.95	2.65
Walrus	Hall Beach	1988	16	9.7	16	1.31	1.25	16	3.01	1.16	16	11.25	5.02
Walrus	Hall Beach	1996	16	14.7	16	1.64	1.26	16	2.66	1.61	15	10.84	6.69
Walrus	Igloolik	1982	13	11.7	16	1.30	1.38	15	2.85	0.92	15	12.35	5.73
Walrus	Igloolik	1983	27	12.6	25	1.34	0.99	24	2.57	1.05	25	9.84	3.81
Walrus	Igloolik	1987	16	8.8	16	1.09	1.02	16	2.73	1.37	15	13.82	8.27
Walrus	Igloolik	1988	15	8.5	13	1.45	1.05	13	2.97	1.52	11	13.25	10.33
Walrus	Igloolik	1996	14	16.6	14	2.41	1.98	14	2.91	1.92	14	12.01	4.71
Walrus	Inukjuaq	1990	8	12.4	9	1.12	0.93	9	2.28	1.07	9	5.28	5.81

The levels of mercury in beluga, narwhal, and ringed seal liver consistently exceeded those in walrus. Beluga samples from a number of locations are included and there is almost as much variability within a site as between different sites. Table 16-9 also includes levels of selenium and cadmium in the same samples but there is no concentration guideline for human consumption with which to compare these values. Levels of cadmium were considerably higher in kidney than in liver.

The ultimate non-human predator in the arctic is the polar bear. Figure 16-34 shows concentrations of mercury in liver of polar bears from 12 areas in the Canadian Arctic. The levels of mercury in bears from the two collections in Hudson Bay were the lowest of all the values obtained. The values given are expressed on a dry weight basis and so they are not directly comparable with human consumption guidelines. Polar bears eat ringed seals but levels of mercury in livers of ringed seals from the Arviat area (Figure 16-30, top panel, wet weight basis) appear to be higher than levels in bear livers (Figure 16-34, dry weight basis). If the seal values were expressed on a dry weight basis, they would be higher yet and the species difference would be even more striking. One might expect the predator to contain higher amounts of mercury than the prey but this is not the case. This discrepancy has been noted by several scientists and explained by the fact that the bears eat only the blubber of the seals, not the protein-rich organs like muscle and liver where more mercury is found (Atwell et al. 1998).

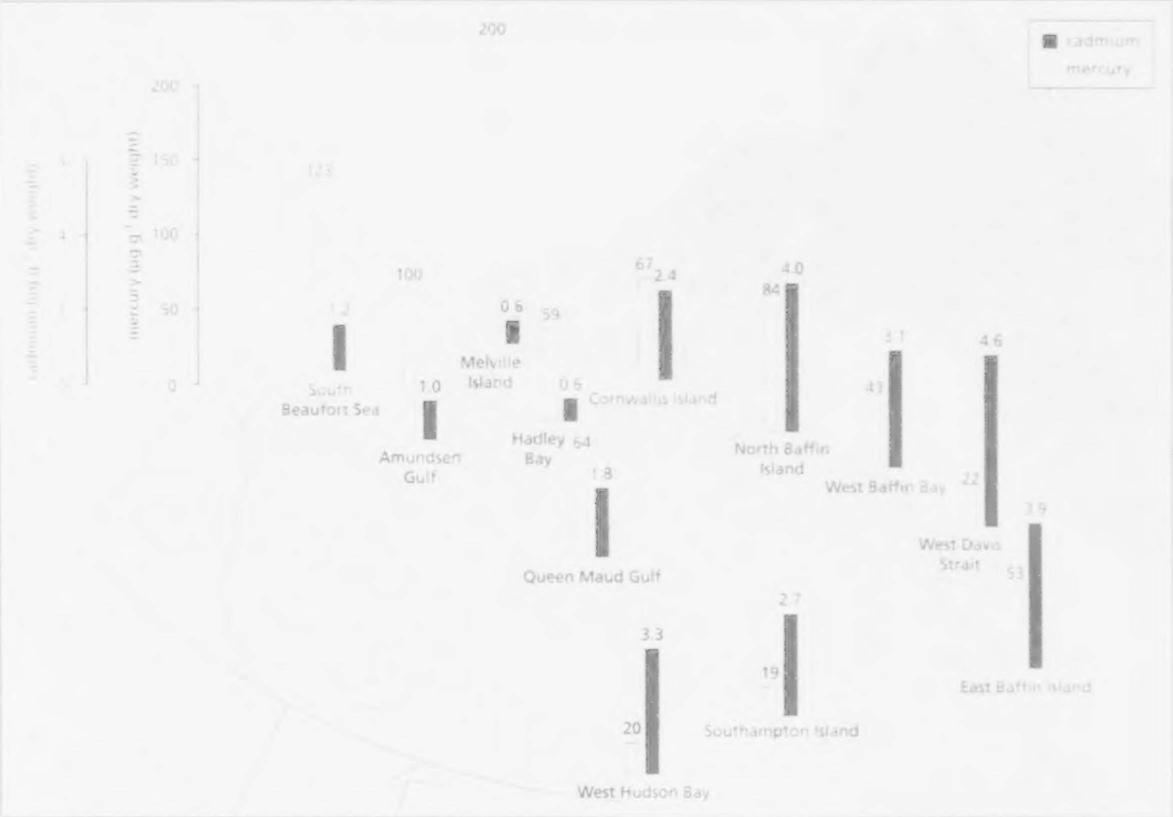

Figure 16-34. Concentrations (age and sex adjusted) of mercury and cadmium (µg·g^{-1} dry weight) in liver of polar bears from 12 areas of the Canadian Arctic. (From CACAR I 1997: Figure 3.3.24, page 247).

The levels of mercury in beluga, narwhal, and ringed seal liver consistently exceeded those in walrus. Beluga samples from a number of locations are included and there is almost as much variability within a site as between different sites. Table 16-9 also includes levels of selenium and cadmium in the same samples but there is no concentration guideline for human consumption with which to compare these values. Levels of cadmium were considerably higher in kidney than in liver.

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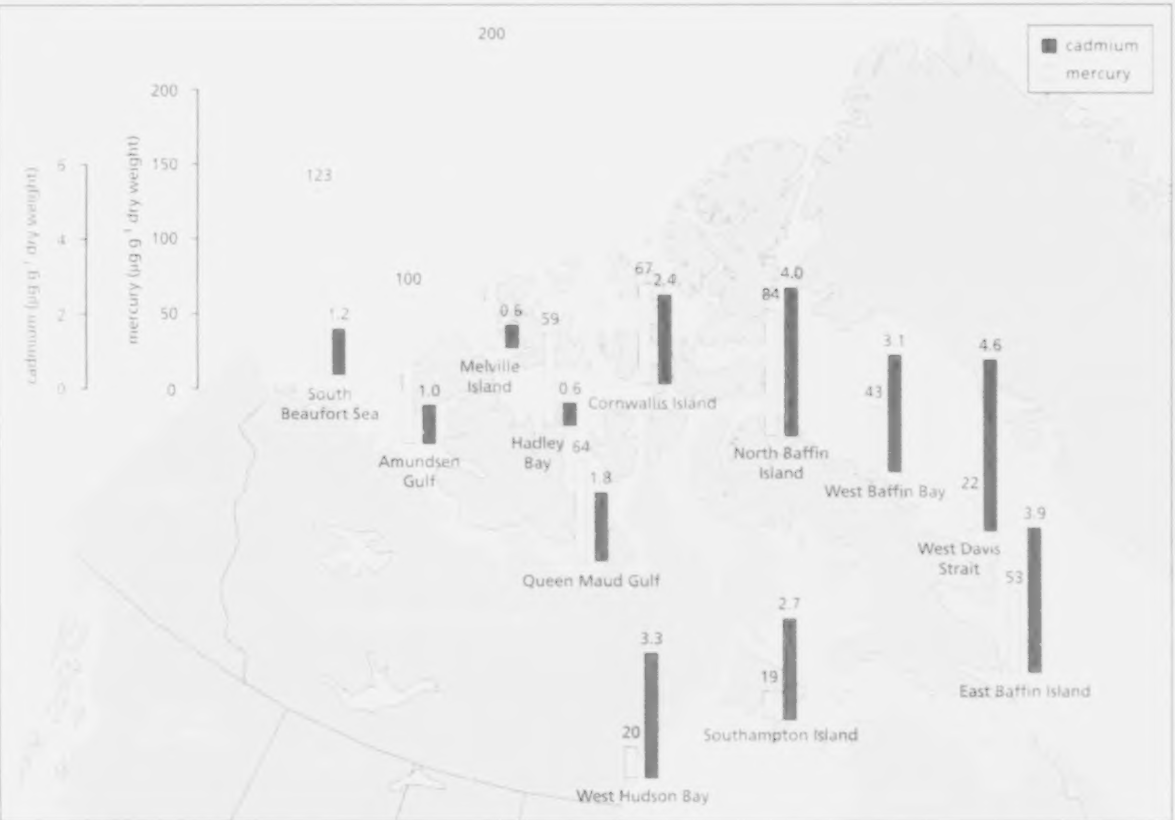

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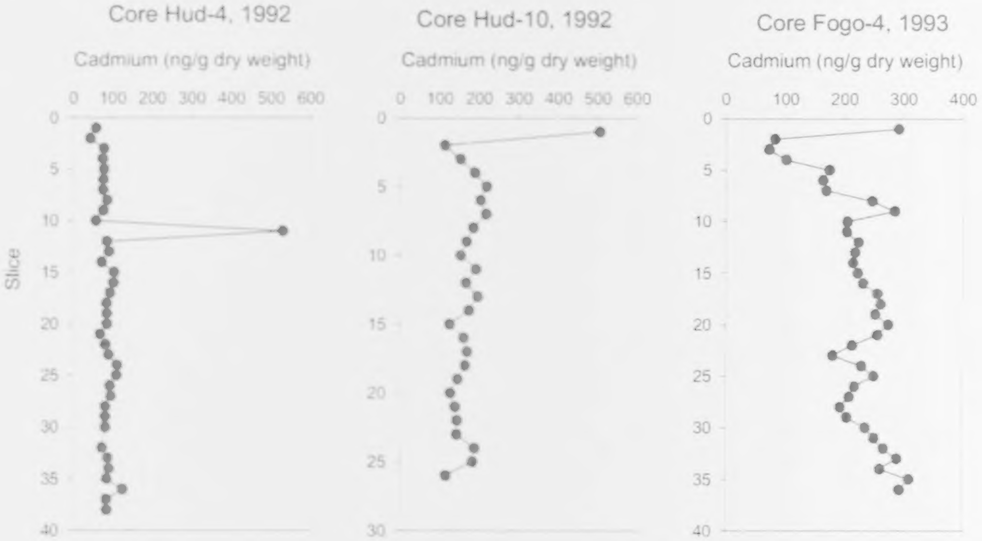
16.12 CADMIUM

Henderson (1989) did not report any analyses of sediments for cadmium. We obtained core profiles for cadmium on the same three cores from southeastern Hudson Bay in 1992 and 1993 mentioned above with regard for lead (Figure 16-10) and mercury (Figure 16-24). The depth profiles for cadmium are shown in Figure 16-35 with most values under 0.3 µg·g^{-1} (300 ng·g^{-1}). Two aberrant values exceeded 500 ng·g^{-1} and may represent contamination errors but even so, no samples reached the ISQG of 700 ng·g^{-1} (0.7 µg·g^{-1}). Since these analyses refer to unfractionated sediment, they can be compared directly with the ISQG value. Twenty-five additional dredge samples were taken in 1995 from the area around Rankin Inlet. The range for these samples was from 0.014 to 0.210 µg·g^{-1}, all well below the ISQG values. McCrea et al. (1984) did not detect cadmium in the sediments of five rivers in Ontario just above the tidal influence of Hudson Bay or James Bay. The sediments available to date do not suggest a contamination problem with cadmium.


Core Hud-4, 1992

Core Hud-10, 1992

Core Fogo-4, 1993

Figure 16-35. **Down-core profiles of cadmium (ng·g^{-1} dry weight) in three sediment cores from southeastern Hudson Bay. Cores Hud-4 and Hud-10 were collected in 1992 and core Fogo-4 was collected in 1993. Locations of core sites are shown in Figure 16-24. (L. Lockhart, unpublished data).**

Cadmium does reach the biota of Hudson Bay. Figure 16-36 shows the concentrations of cadmium in kidneys of eider ducks from two locations in Hudson Bay and from Holman Island in the western Arctic. The highest mean value was 40.8 µg·g^{-1} wet weight in king eider from Southampton Island. The threshold for cadmium poisoning in birds is reported to be greater than 100 µg·g^{-1} wet weight in liver (CACAR II 2003: Biological Environment, Table 5.3.2, page 99) and so the present levels in eiders do not appear to represent a risk to the birds. No indication of the variance was given in Figure 16-36 and so it is possible that some small proportion of the birds reach the threshold concentration. Figure 16-30 includes a panel showing levels of cadmium in liver of ringed seals from several locations in northern Canada. The value given for cadmium in liver of seals from Arviat was about 12 µg·g^{-1}. Again, this appears to be below the threshold for biological effects which is 20-200 µg·g^{-1} (CACAR II 2003: Biological Environment, Table 5.3.2, page 99). The error bar on the graph suggests that a small proportion of the seals would reach or exceed the lowest part of the effects range. The seals from Pangnirtung, however, had mean liver cadmium of about 18 µg·g^{-1} and the error bar extended well above 20 µg·g^{-1} and so cadmium probably poses a greater risk to that stock of seals.

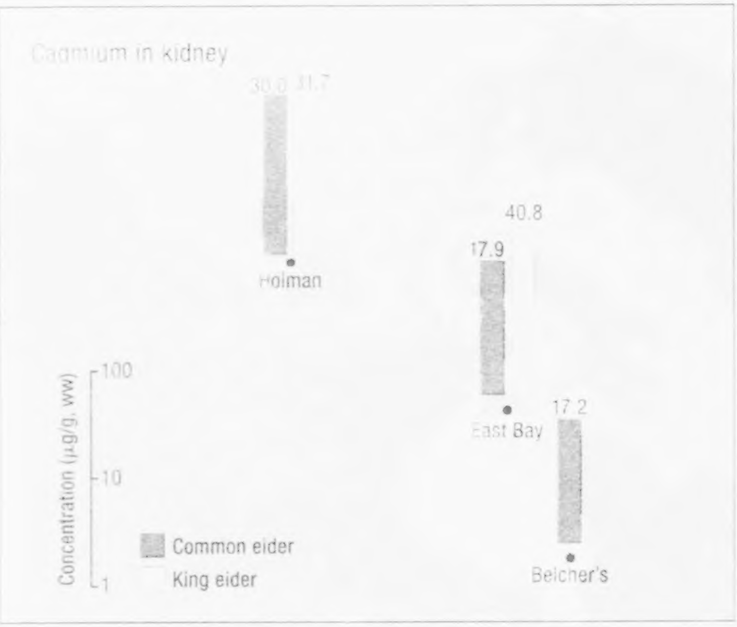


Figure 16-36. Mean levels of cadmium (µg·g^{-1} wet weight) in kidneys of eider ducks. (From CACAR II 2003: Biological Environment, Figure 3.2.2, page 25).

16.13 RADIONUCLIDES

CACAR I (1997) reviewed the status of radiunuclides in the Canadian Arctic. The greatest human exposure derives from the natural radionuclides lead-210 and its decay product, polonium-210. Both are derived from radon-222 gas, which in turn derives from radium-226 and ultimately from uranium in the soils. Presumably the exposure of northern ecosystems to these natural radionuclides has been occurring for thousands of years. The fission of uranium in bombs and nuclear reactors results in production of several artificial radionuclides and three of these are of concern in the environment, namely iodine-131, cesium-137 and strontium-90. Most atmospheric testing of nuclear bombs was stopped in 1963 by international agreement, however, France and China were not parties to the agreement and they continued atmospheric testing until 1980. Cesium isotopes, Cs-134 and Cs-137 are considered to be the artificial isotopes of greatest concern. The Chernobyl reactor accident in Ukraine in 1986 also contributed Cs-137 and Cs-134 to the Canadian North. Very small amounts of these isotopes have reached Hudson Bay. Figure 16-37 includes a profile of Cs-137 in sediment from Core Hud-4 from southeastern Hudson Bay in 1992. Judging by that profile, peak inputs occurred in the 1960s with a gradual decline since then.

The natural radionuclides polonium-210, radium-226, thorium-230, thorium-232, uranium-234, and uranium-238 were measured in a series of samples collected from the surface sediments of Hudson Bay in 1995 from the area near Rankin Inlet. These levels are plotted in the maps shown in Figure 16-37. The ranges for the different colours of dots were selected by MapInfo software to show approximately equal numbers of points in each range. The red dots represent samples with the highest levels of these radionuclides and they were usually closest to the community of Rankin Inlet. The levels of Ra-226 and its distant decay daughter Po-210 had some values in the high range further offshore near the island to the east of the community. These samples were examined analyzed for particle size distribution in the Geology Department, University of Manitoba, and the radionuclide concentrations were examined for statistical relationships to water depth and proportions of sand, silt and clay (Appendix 8). The two isotopes of uranium were associated statistically with fine particles (silt and clay), but there were few other statistical relationships between individual radionuclides and particle sizes. The cesium-137 was negatively correlated with the sand content but the correlation coefficient was significant at $p<0.06$, just

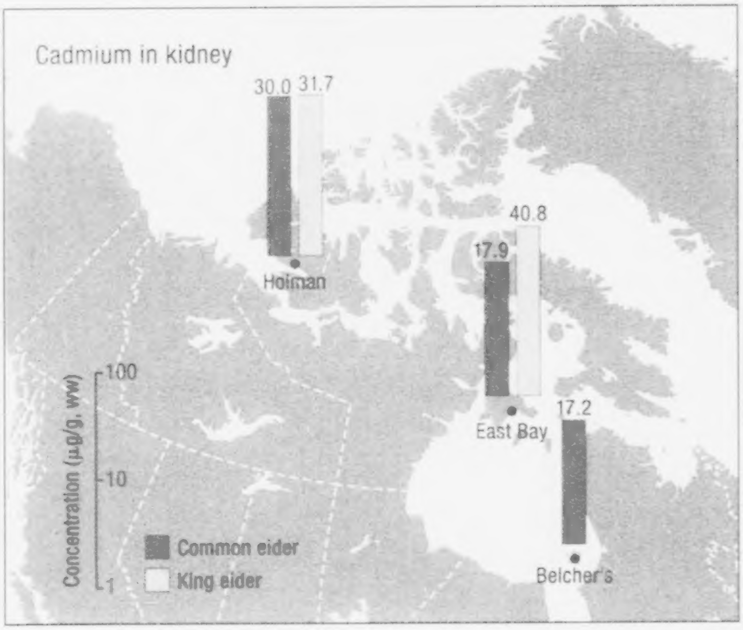


Figure 16-36. **Mean levels of cadmium (µg·g^{-1} wet weight) in kidneys of eider ducks. (From CACAR II 2003: Biological Environment, Figure 3.2.2, page 25).**

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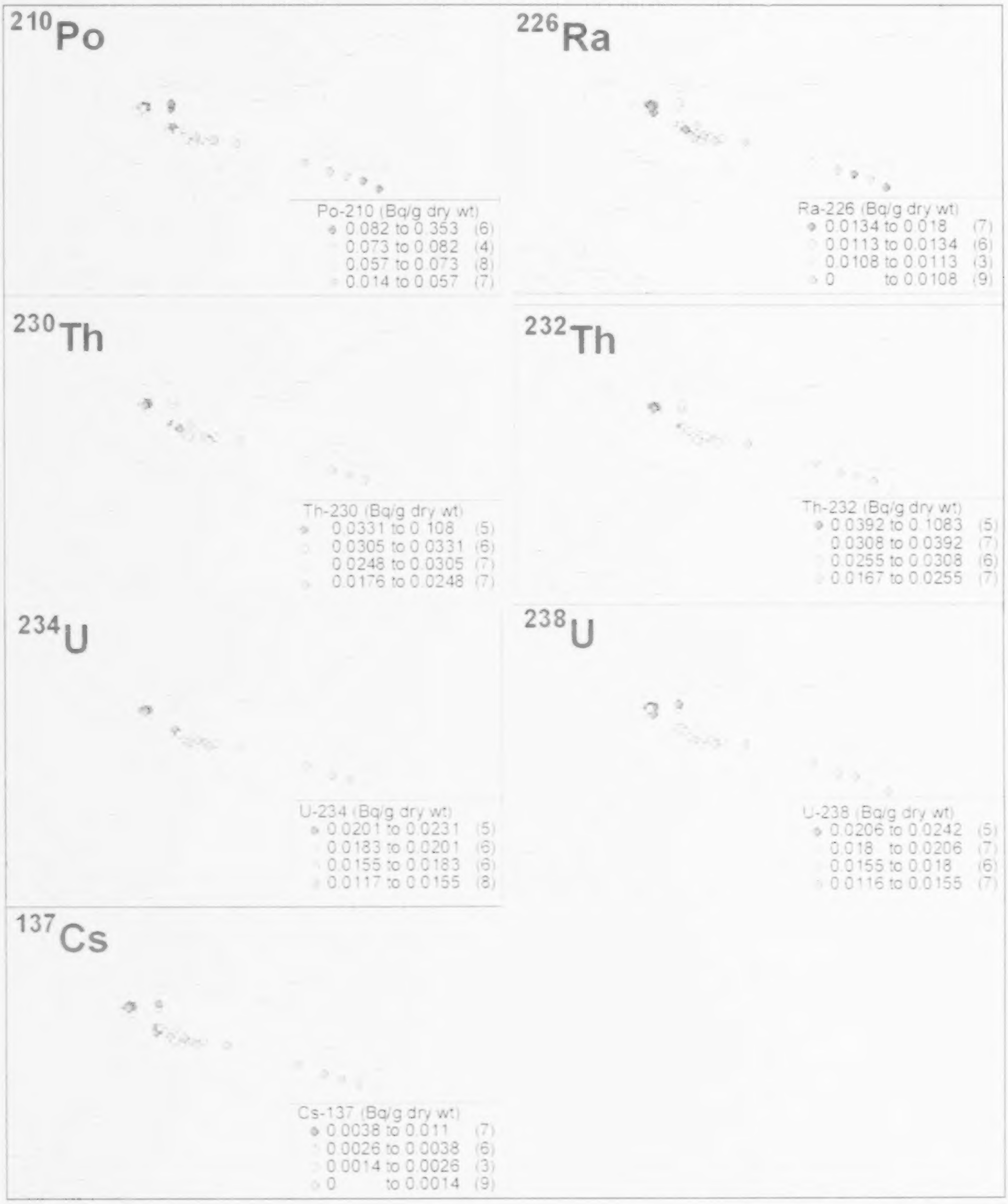


Figure 16-37. **Radionuclides (Bq·g^{-1} dry weight) in surface sediment from Hudson Bay in the vicinity of Rankin Inlet, 1995. The colour ranges were selected by MapInfo software to contain approximately the same number of points in each range (L. Lockhart, unpublished data).**

The distribution of the man-made radionuclide, cesium-137 is also shown in Figure 16-37 and its distribution is similar to that for the uranium and thorium isotopes. The down-core profile of cesium-137 in a core from southeastern Hudson Bay was shown also in Figure 16-3 and cited as evidence that anthropogenic activities have effects on Hudson Bay. The source of cesium-137 in this area was atmospheric testing of nuclear bombs and most of that stopped in 1963 by international agreement; subsequent inputs have fallen dramatically. There have been point source discharges to the ocean (e.g., Sellafield, U.K.) but it is unlikely that these are responsible for the Cs-137 found in Hudson Bay. The levels shown in Figure 16-37 may be compared with earlier measurements from the area around Baker Lake reported by Svoboda et al. (1985) on samples collected in 1981 and 1982. The earlier figures are generally higher than those for marine sediments collected in 1995 near Rankin Inlet (Figure 16-38). The radiological half-life of cesium-137 is 30 years and more than half of the amounts present in 1981/82 would still be present in 1995. Radioactive decay would be expected to bring the freshwater samples by Svoboda et al. (1985) into close agreement with the marine sediments in 1995. The same comparison is also possible for radium-226 (Figure 16-39) and the values for the freshwater drainages are highly variable as would be expected in a region with locally enriched deposits of uranium. Radium-226 has a long radiological half-life of 1622 years and so the difference in the times when the samples were collected is insignificant for this isotope. The main value in these measurements may be as basal information for evaluation when commercial developments of uranium ores in regions around Baker Lake or Foxe Basin take place.

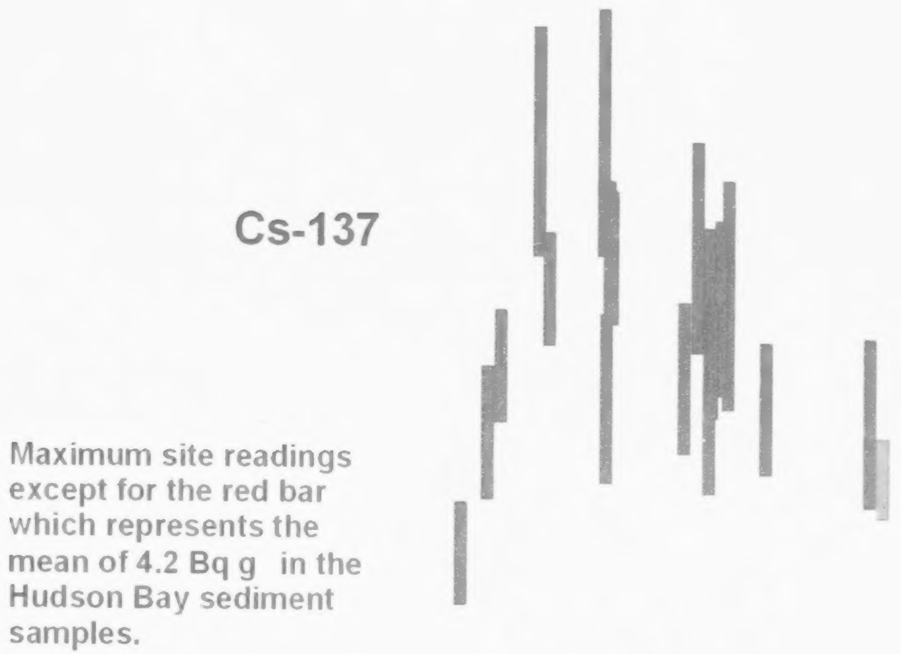


Figure 16-38. **Cesium-137 (Bq·g^{-1}) in vegetation and substrate as reported by Svoboda et al. 1985 (blue bars), from collections made in 1981 and 1982. The red bar is the mean for marine sediment samples collected near Rankin Inlet in 1995 (L. Lockhart, unpublished data).**

Ra-226

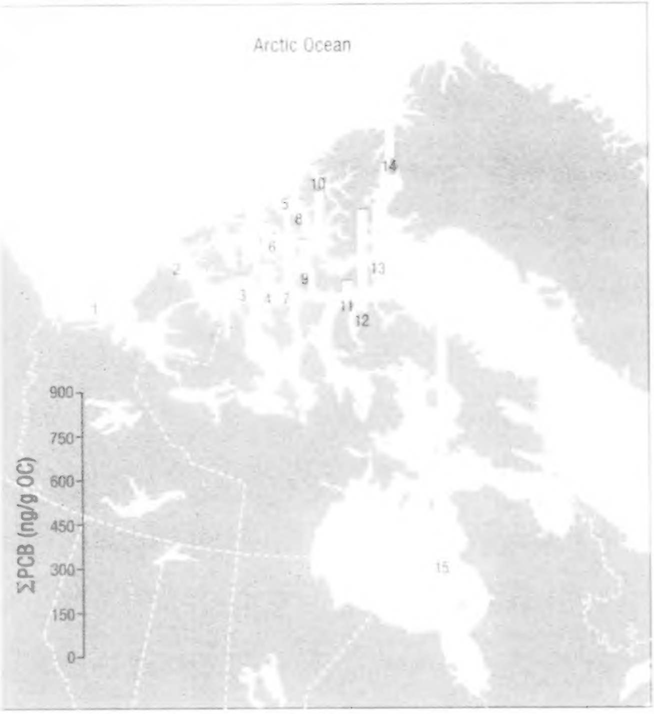
Maximum site readings except for the red bar which represents the mean of 12.2 Bq g in the Hudson Bay sediment samples.

Figure 16-39. **Radium-226 (Bq·g^{-1}) in vegetation and substrate as reported by Svoboda et al. 1985 (yellow bars), from collections made in 1981 and 1982. The red bar is the mean for marine sediment samples collected near Rankin Inlet in 1995 (L. Lockhart, unpublished data).**

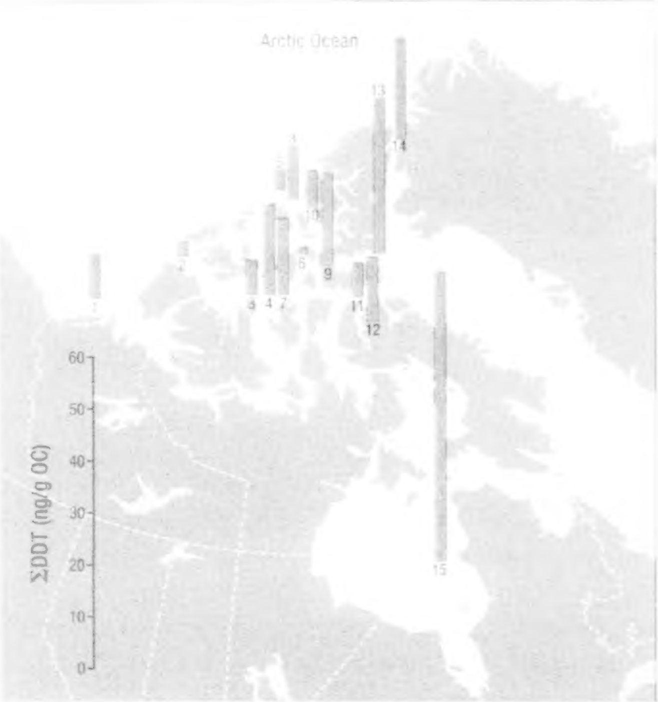
Little information exists on radionuclides in the aquatic biota of Hudson Bay. Appendix 8 lists some unpublished data from the early 1980s for several radionuclides in animals taken in the vicinity of Saqvaqjuaq. With the exception of cesium-137, the time elapsed since sampling would not be expected to have changed the exposure since all the other radionuclides are of natural origin and their presence is sustained by the presence of long-lived parent radionuclides. For example, the levels of the relatively short-lived isotope, polonium-210 are sustained by the presence of its parent isotope, lead-210, which is in turn supported by radon gas and then by radium-226. Levels of cesium-137 in animals today will have fallen below the values recorded in the early 1980s because the half-life of cesium-137 is only 30 years and inputs of new Cs-137 have fallen dramatically.

16.14 SYNTHETIC ORGANIC COMPOUNDS IN THE BIOTA OF HUDSON BAY

DDT and its metabolite, DDE, were identified in samples of soil, vegetation, and a variety of animals, mostly birds, from the Churchill area in 1967. Brown and Brown (1970) compared residues in areas sprayed with DDT (for control of mosquitoes) and in nearby unsprayed areas and found DDT and DDE present consistently in both areas. Having reached the Arctic environment by various pathways (e.g., Figure 16-1), synthetic compounds have become incorporated into both the physical and biological components of the Arctic. Several contaminants move through food chains to become concentrated in animals at high trophic levels. Following are a few examples that show levels of organochlorine compounds in arctic samples. Few data exist describing organic contaminants in Hudson Bay sediments. Figure 16-40 shows bar graphs of PCBs and DDT in Arctic marine sediments and only one sample is reported from Hudson Bay (from core Fogo-4, location shown in Figure 16-24). That sample, however, had the highest levels of both DDT and PCBs (per gram of organic carbon) among the locations reported.



	ΣPCB	Site
1	**80** ng/g OC	Beaufort
2	**15** ng/g OC	M'Clure St
3	**40** ng/g OC	V. Melville Sd
4	**88** ng/g OC	Barrow St.
5	**33** ng/g OC	Peary Ch
6	**9.6** ng/g OC	Penny St
7	**170** ng/g OC	Barrow St.
8	**37** ng/g OC	Massey Sd
9	**98** ng/g OC	Wellington Ch
10	**150** ng/g OC	Norwegian Bay
11	**54** ng/g OC	Lancaster Sd
12	**350** ng/g OC	Strathcona Sd
13	**190** ng/g OC	Jones Sd
14	**120** ng/g OC	N. Baffin Bay
15	**920** ng/g OC	E. Hudson Bay



	ΣDDT	Site
1	**8.6** ng/g OC	Beaufort
2	**2.5** ng/g OC	M'Clure St
3	**6.0** ng/g OC	V. Melville Sd
4	**17** ng/g OC	Barrow St
5	**3.7** ng/g OC	Peary Ch
6	**1.2** ng/g OC	Penny St
7	**14** ng/g OC	Barrow St
8	**10** ng/g OC	Massey Sd
9	**18** ng/g OC	Wellington Ch
10	**6.8** ng/g OC	Norwegian Bay
11	**6.2** ng/g OC	Lancaster Sd
12	**12** ng/g OC	Strathcona Sd
13	**30** ng/g OC	Jones Sd
14	**19** ng/g OC	N. Baffin Bay
15	**56** ng/g OC	E. Hudson Bay

Figure 16-40. PCB (above) and DDT (below) (ng·g^{-1} organic carbon) in Arctic marine surface sediments. (from CACAR II 2003: Physical Environment, Figure B.3.2, page 101).

16.14.1 Plankton and fish

Organochlorine contaminants have been measured in plankton samples (Figure 16-41). For example, PCBs have been measured in zooplankton from the Rankin Inlet area at about 50 ng·g^{-1} (dry weight), slightly higher than other northern Canadian locations, although the number reports on plankton to date is very small. The levels of PCBs in anadromous Arctic charr were somewhat higher than in plankton (Figure 16-42), the value for charr from Sanikiluaq in the early 1990s being about 25 µg·g^{-1} wet weight. Considering that the plankton was about 50 ng·g^{-1} dry weight, and taking the moisture content to be about 80 per cent, the value for plankton on a wet weight basis might have been of the order of 10 ng·g^{-1}. Figure 16-43 shows PCBs and several other organochlorines in sea birds from the Northwater polynya with values for PCBs about 200 to 9000 ng·g^{-1} of fat in liver. The CACAR II (2003: Biological Environment) report tabulated the same or similar data in units of ng·g^{-1} wet weight and the values ranged from about 15-450 ng·g^{-1}. The most highly contaminated tissue was body fat from ivory gull, glaucous gull, and northern fulmar, the maximum value being 11719 ng·g^{-1} in glaucous gull. We do not have comparable data for birds from Hudson Bay, but similar values would be anticipated.

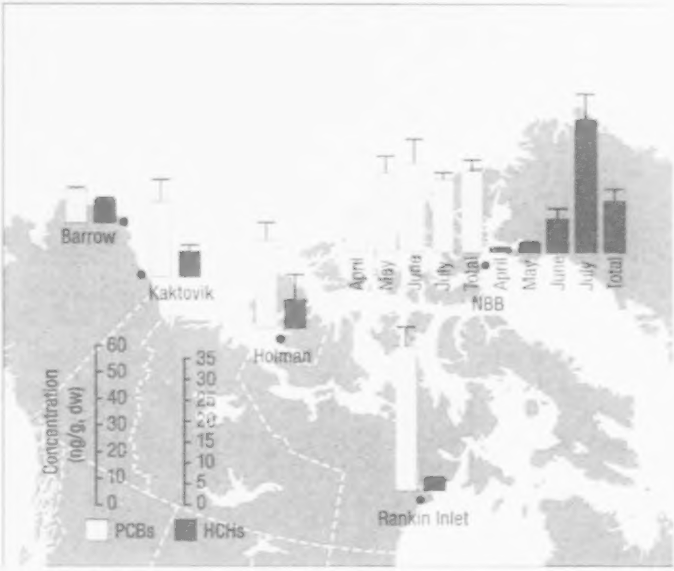


Figure 16-41. **PCBs and HCHs (ng·g^{-1} dry weight) in zooplankton from several northern locations including Rankin Inlet. (From CACAR II 2003: Biological Environment, Figure 3.3.3, page 30).**

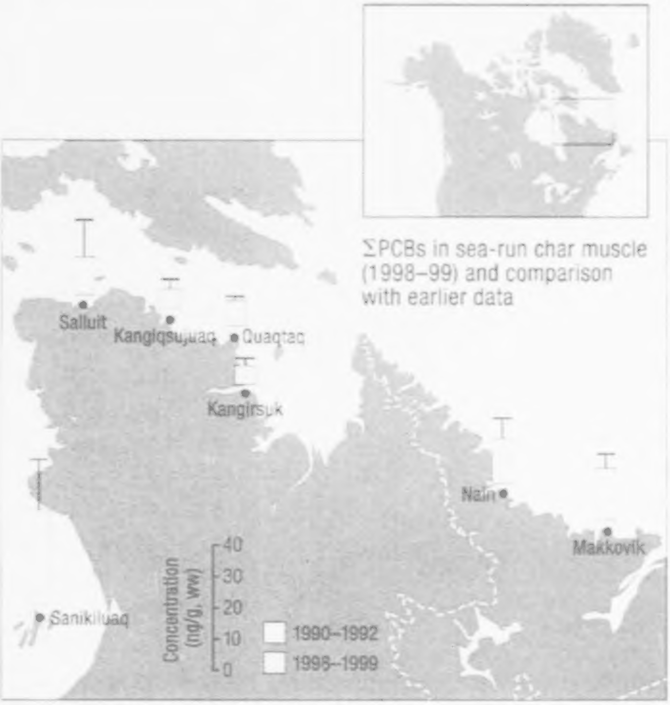


Figure 16-42. **PCBs (ng·g^{-1} wet weight) in muscle of sea-run Arctic charr from several communities in 1998-1999 and from Salluit and Sanikiluaq in 1990-1992. (From CACAR II 2003: Biological Environment, Figure 3.3.5, page 32).**

16.14.2 Ringed seal

The first Canadian Arctic Contaminants Assessment Report (1997) tabulated levels of chlorobenzenes, hexachlorocyclohexanes, chlordanes, DDTs, PCBs, toxaphenes, and dieldrin in blubber of ringed seals, beluga, and walrus from Hudson Bay. Figure 16-44 shows the levels of PCBs and DDT in seal blubber collected from 1989-1994. The data were presented as two bars for each location showing male and female seals separately. The levels of both PCBs and DDT were usually higher in male seals than in females. This gender difference has been observed by several investigators and is thought to be the result of females secreting

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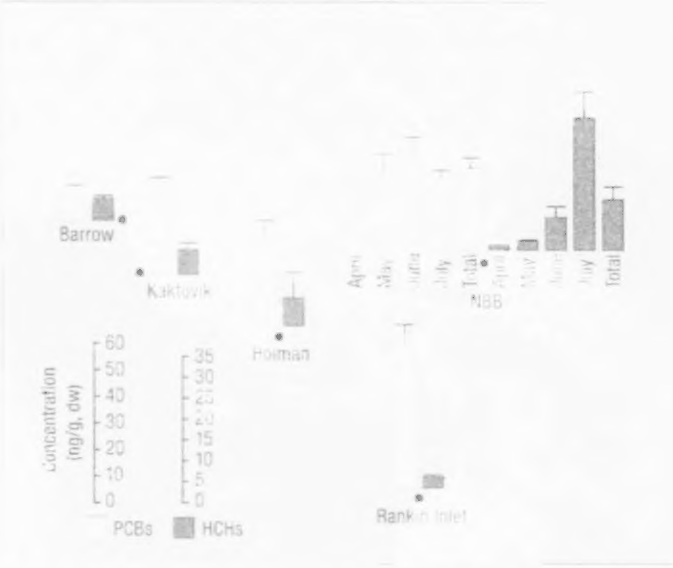

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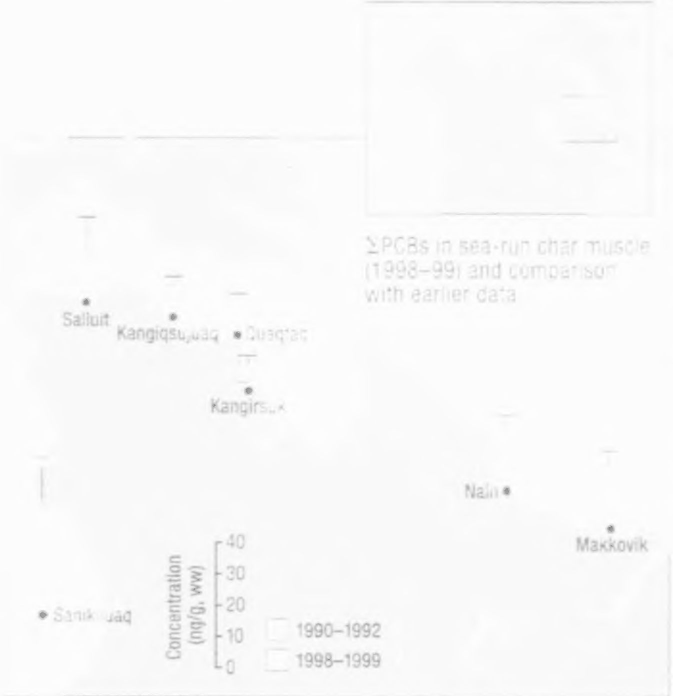

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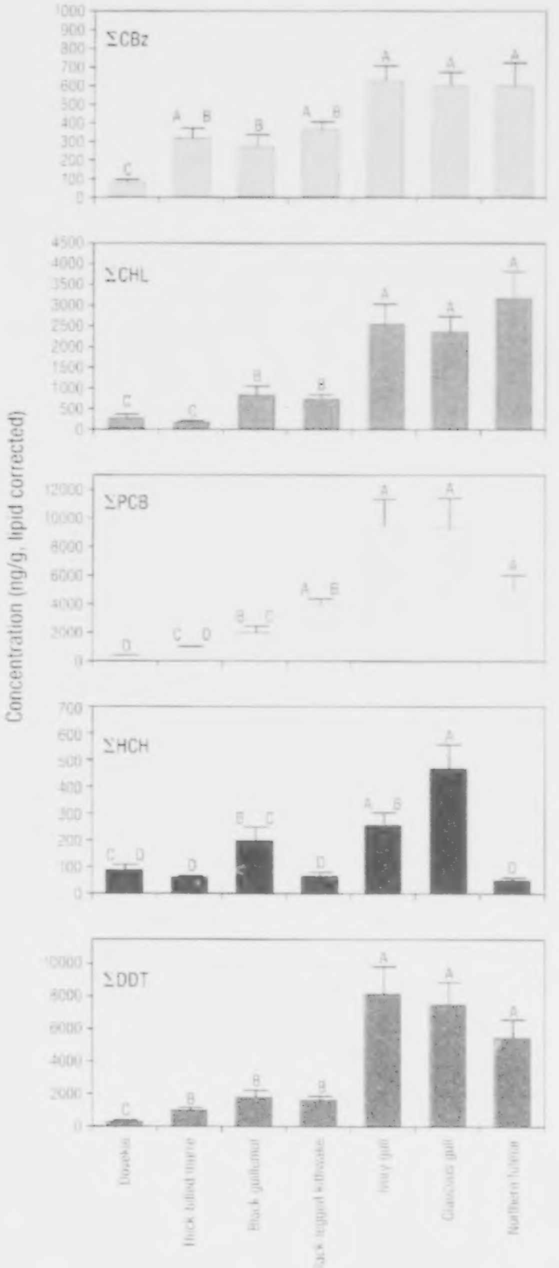


Figure 16-43. Organochlorine residues (ng·g^{-1}, lipid corrected) in liver of sea birds from the Northwater Polynya in northern Baffin Island. Bars with the same letter do not differ statistically. (From CACAR II 2003: Biological Environment, Figure 3.3.10, page 36).

16.14.3 Beluga

PCB levels in blubber of beluga from Hudson Bay were higher than those in ringed seals (Figure 16-46). The mean concentration in male beluga from western Hudson Bay in 1992-95 was about three times higher than it was in the seals. Beluga males from eastern Hudson Bay had blubber PCBs at 6.4 µg·g^{-1} but females had only 2.2 µg·g^{-1}. Only a few more recent data on beluga from the Hudson Bay region are available. The CACAR II (2003) report lists mean concentrations of PCBs in beluga blubber from the Nastapoca area of eastern Hudson Bay in 1999 as 2220 ng·g^{-1} (2.25 µg·g^{-1}) in females and 3550 ng·g^{-1} (3.55 µg·g^{-1}) in males (CACAR II 2003: Biological Environment, Annex Table 10). This suggests the unlikely situation of a decline in levels in males with no change in females. A more complete series of beluga samples from Pangnirtung (1982, 1986, 1992, 1996/97) was reported by Stern and Addison (1999). In that study, PCB congeners were measured individually in blubber of male beluga and adjusted for effects of age and fat content. The levels of all the different PCBs declined over the 15-year period from 1982 to 1997. For example, the concentration of PCB-

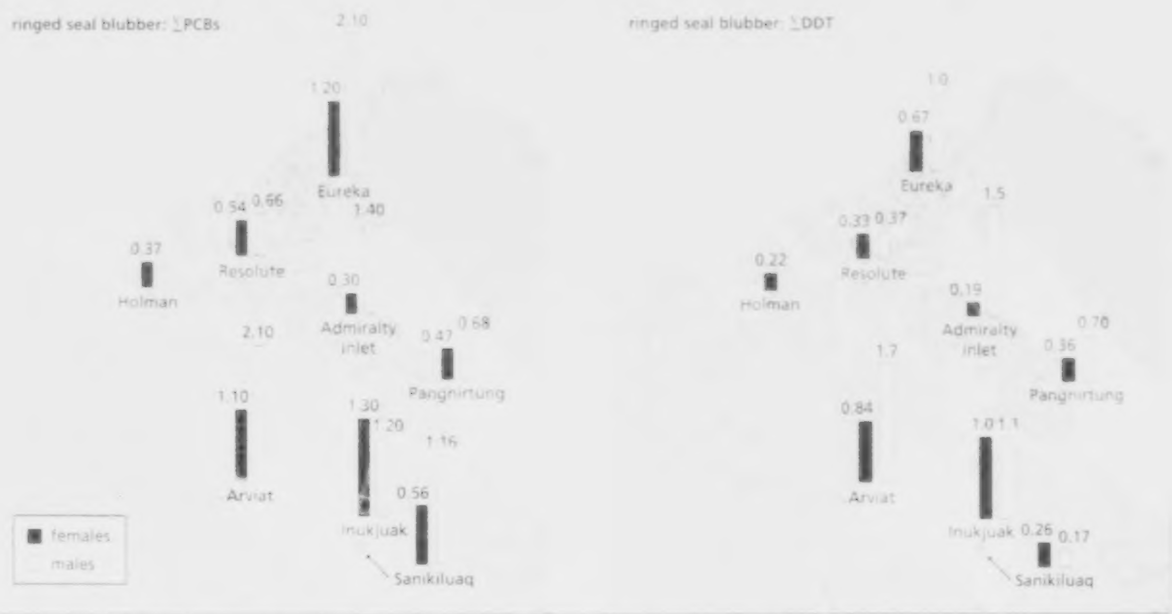


Figure 16-44. PCBs and DDT ($\mu g \cdot g^{-1}$ wet weight) in blubber of ringed seals collected from 1989 to 1994 from northern communities. (From CACAR I 1997: Figure 3.3.20 A, page 238).

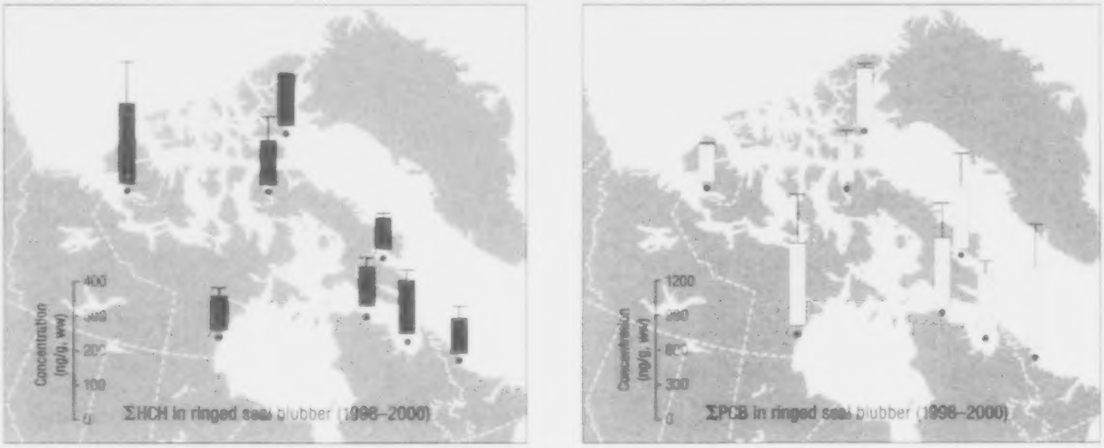

Concentration (ng/g, ww)
400
300
200
100
0
ΣHCH in ringed seal blubber (1998–2000)
Concentration (ng/g, ww)
1200
900
600
300
0
ΣPCB in ringed seal blubber (1998–2000)

Figure 16-45. PCBs and HCHs ($ng \cdot g^{-1}$ wet weight; mean and 95% confidence interval) in blubber of female ringed seals collected between 1998 and 2000. (From CACAR II 2003: Biological Environment, Figure 3.3.14, page 42).

169 was about 220 $pg \cdot g^{-1}$ lipid in 1982 and it had fallen to about 115 $pg \cdot g^{-1}$ lipid in 1996/97 (Stern and Addison, 1999, page 208). For DDT, however, no clear temporal change was observed in the levels of total DDT, although the ratio between p,p'-DDT and ∑DDE increased suggesting that 'old' DDT was sustaining the levels rather then inputs of 'new' DDT. Levels of chlordane components have increased over the period while levels of dieldrin have fallen. Overall, there is no single pattern applicable to organochlorine compounds in general. Some have increased in the Pangnirtung samples, some have decreased, and some have remained unchanged. One can speculate that an equally complex picture will emerge from studies of Hudson Bay beluga.

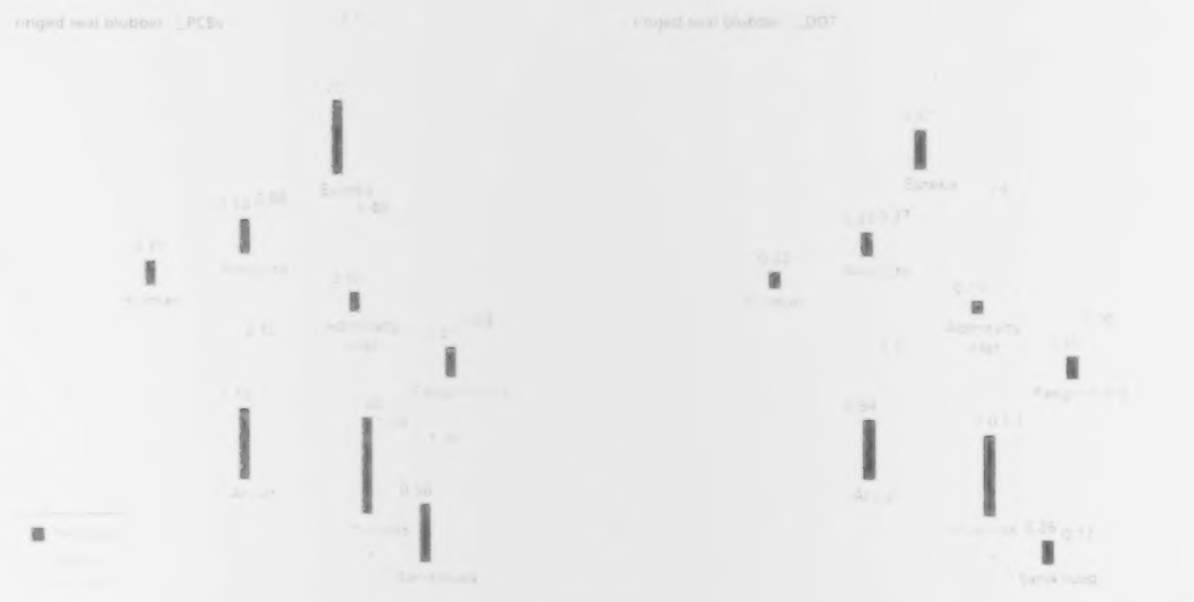
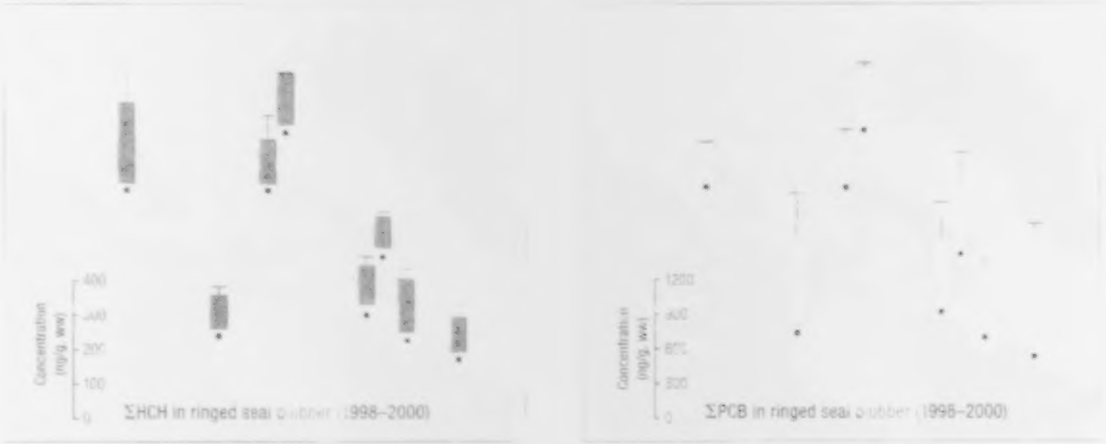


Figure 16-44. PCBs and DDT (µg·g⁻¹ wet weight) in blubber of ringed seals collected from 1989 to 1994 from northern communities. (From CACAR I 1997: Figure 3.3.20 A, page 238).



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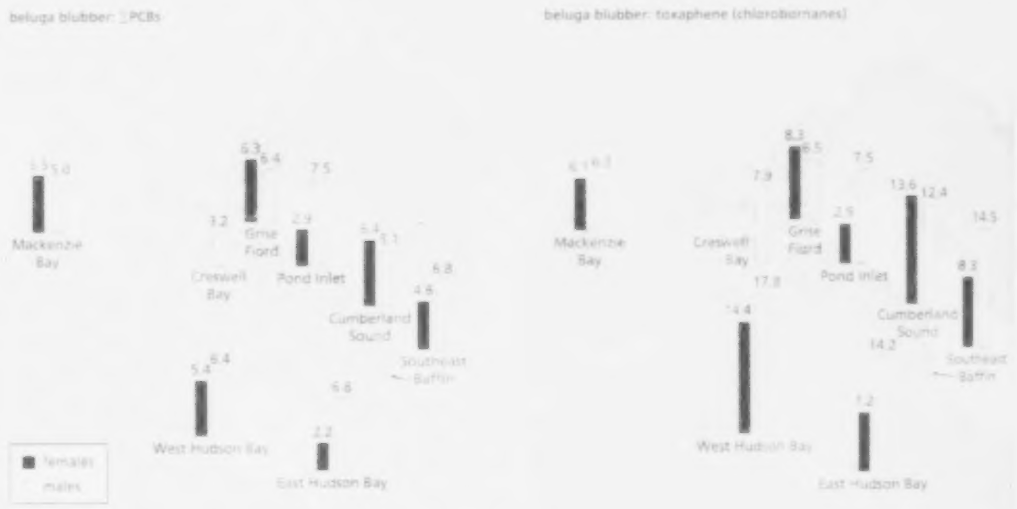

Figure 16-46. PCBs and toxaphene (μg·g^{-1} wet weight) in blubber of beluga whales collected from 1992 to 1995 from northern communities (From CACAR I 1997, Figure 3.3.20B, page 238.).

16.14.4 Polar Bear

Concentrations of several organochlorine compounds in fat of mature polar bears from the Churchill area have been measured several times over the period 1969-1998 (Figure 16-47). Recent levels of ΣPCBs were under 3000 ng·g^{-1} and all the other organochlorines reported were lower yet. The most consistent change is the decline in ΣDDT over the period from about 850 ng·g^{-1} in 1968 to about 250 ng·g^{-1} in 1999. CACAR II (2003) authors speculated that this decline is not typical of other arctic data and might have been related to cessation of spraying DDT for the control of forest insects in the Hudson Bay watershed. ΣCBz appears to have increased between 1969 and 1984 and to have declined continuously since then. Similarly, levels of σHCH have declined since 1984 but levels of ßHCH have not, with the result that the blend of the components ΣHCH has changed over the period. Similarly, PCBs have declined during the 1990s but with a change in the composition of the mixture of PCB congeners in the bears. The proportion of less chlorinated congeners has increased while the proportion of highly chlorinated congeners has fallen with the result that no long-term trend in ΣPCBs since 1968 is evident.

16.15 POTENTIAL FOR BIOLOGICAL EFFECTS OF ORGANOCHLORINE CONTAMINANTS

Some of the measurements of ΣPCB and ΣDDT in northern fish are shown in Figure 16-48 along with current estimates of the amounts required to cause biological harm. Several of the levels of both ΣPCB and ΣDDT exceed the guidelines set for the protection of birds and mammals that consume aquatic life. Levels in two groups of fish (burbot from Kusawa Lake, YK, and Greenland shark from Cumberland Sound, NU) exceed levels required for induction of biochemical responses (EROD, liver enzyme Ethoxyresorufin-O-deethylase). Figure 16-49 shows similar information for birds. Fortunately, in this instance all of the chemical residues reported are well below thresholds for biological effects. The situation is less clear in marine mammals (Figure 16-50) where ringed seal, beluga, narwhal, arctic fox and polar bear all exceed at least one no-effect level. Overall these comparisons suggest that animals at the top of arctic food chains may be at some risk of subtle biological effects from their intakes of organochlorine compounds.

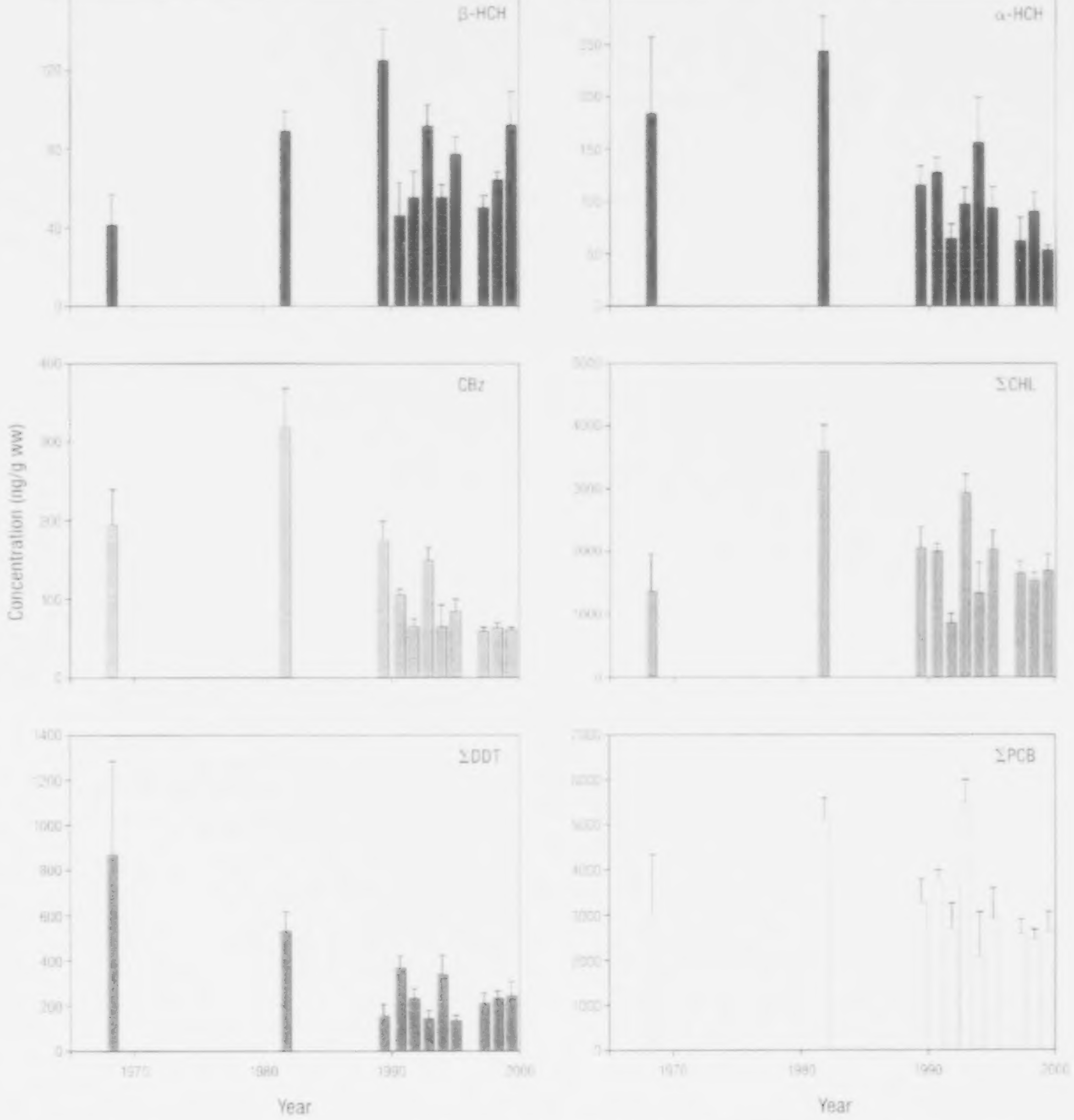

Figure 16-47. Organochlorine compounds (ng·g^{-1} wet weight) in fat of polar bears from the Churchill area from 1968 to 1999. Samples from 1991-1999 are fat biopsies; earlier samples are adipose tissue. (From CACAR II 2003: Biological Environment, Figure 4.3.6, page 76).

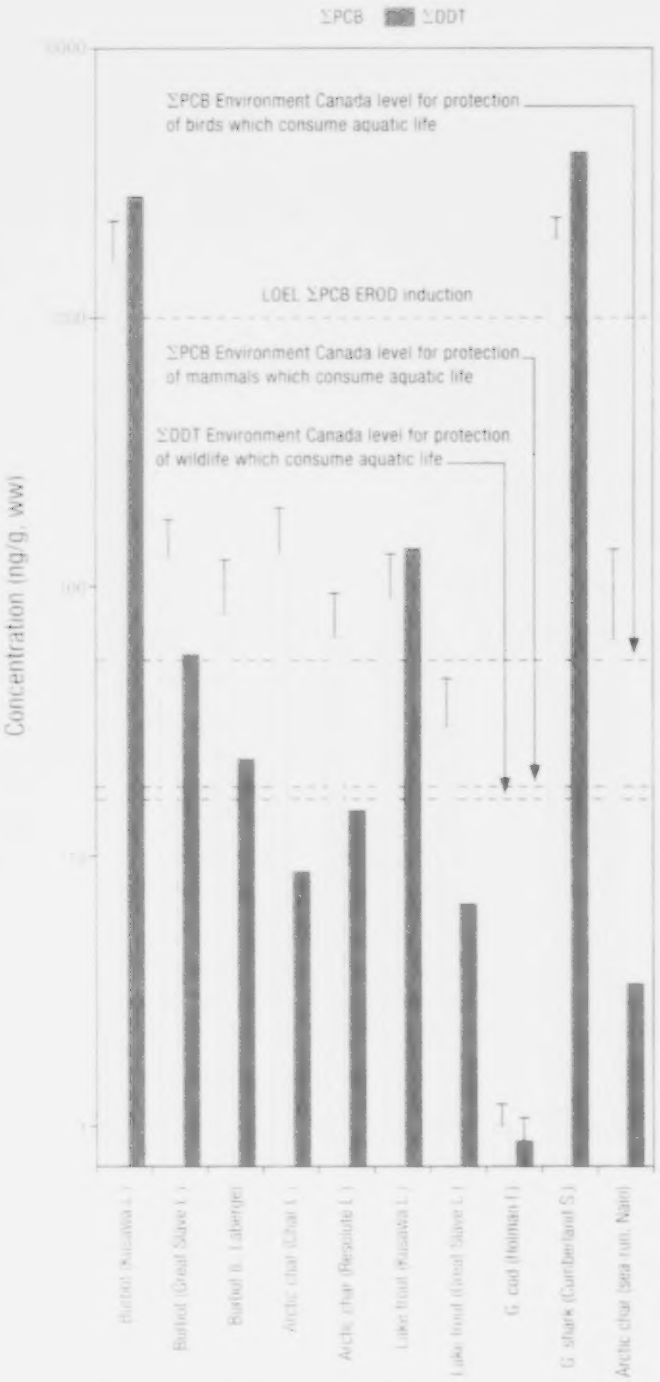

Figure 16-48. Average ΣPCB and ΣDDT levels in freshwater and marine fish compared with threshold effects levels and Environment Canada guidelines for the protection of aquatic life. References to Environment Canada guidelines and LOEL information are given in CACAR II (2003). This comparison should be used with caution because of extrapolations across tissues and species. (From CACAR II 2003: Biological Environment, Figure 5.3.1, page 96).

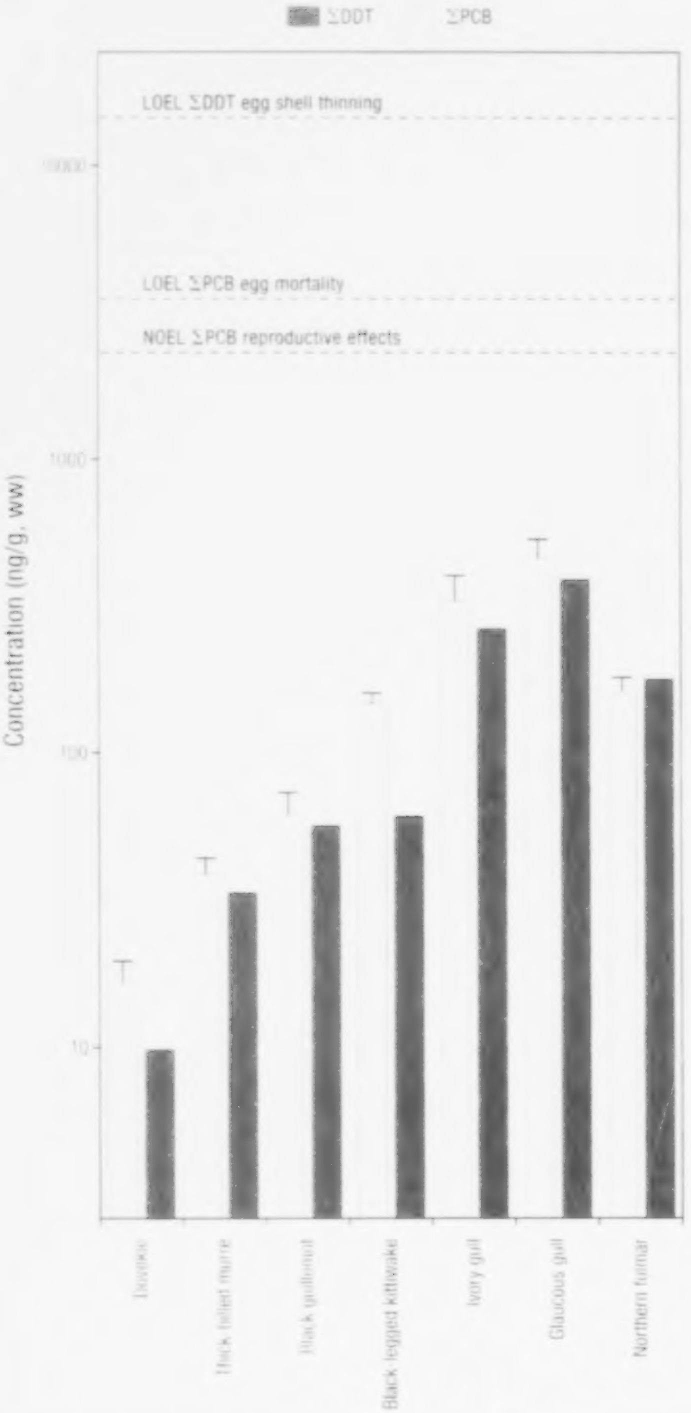

Figure 16-49. Average ΣPCB and ΣDDT levels in livers of seabirds compared with threshold effect levels. This comparison should be used with caution because of extrapolations across tissues and species. (From CACAR II 2003: Biological Environment, Figure 5.3.2, page 97).

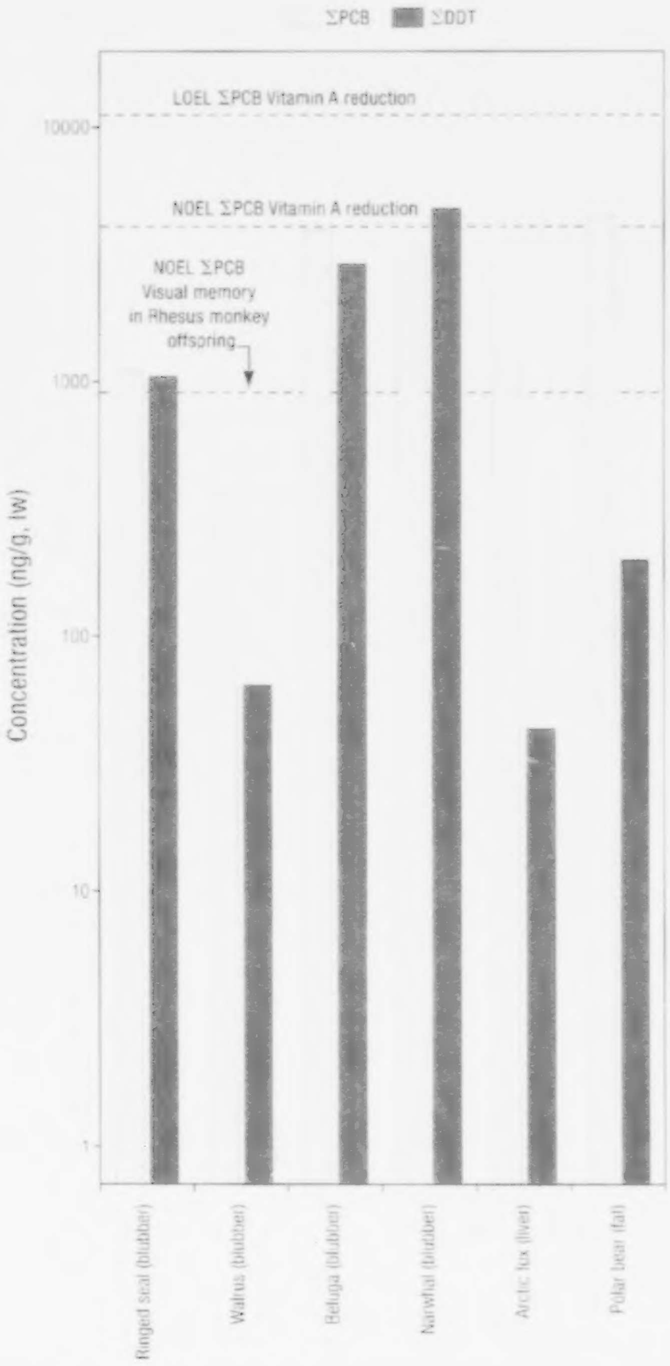

Figure 16-50. Average ΣPCB and ΣDDT levels in marine mammals compared with threshold levels for biological effects. This comparison should be used with caution because of extrapolations across tissues and species. (From CACAR II 2003: Biological Environment, Figure 5.3.4, page 98).

16.16 STABLE ISOTOPES AND ACCUMULATION OF CONTAMINANTS IN ANIMALS

A recent technique has become an important part of studies aimed at understanding the levels of contaminants in arctic animals. Through the use of stable isotopes of nitrogen, it has become possible to make a quantitative estimate of the trophic level at which an animal has been feeding. The CACAR II (2003: Biological Environment) report shows the graphical relationship between trophic level and the concentration of PCB-180 in a range of aquatic organisms and sea birds (Figure 16-51). It is apparent that the trophic level was an important predictor of the level of this PCB congener to be expected in the animals and it seems likely that this will be an important component of future studies.

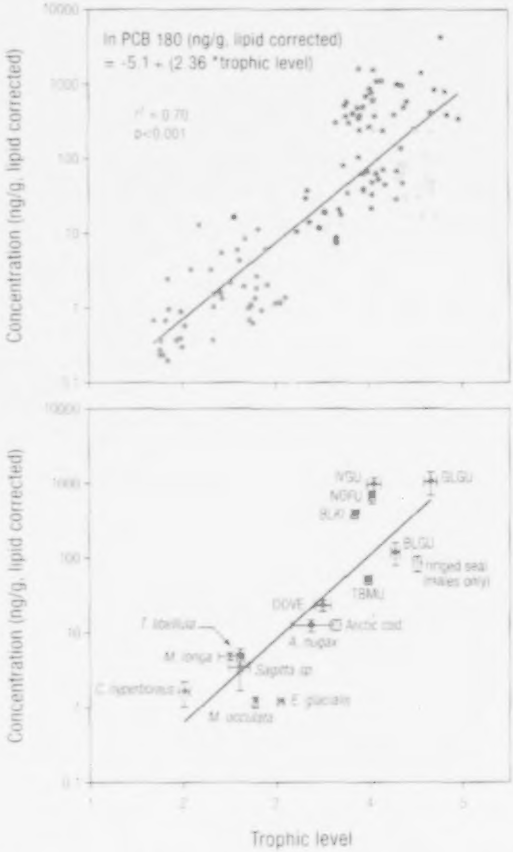

Figure 16-51. **PCB 180 concentrations (ng·g^{-1}, lipid corrected) and trophic status in species from the North Water Polynya. The top graph contains all the data points and the lower graph contains the mean (± S.E.) for each species. Trophic levels are assigned based on the nitrogen isotope ^{15}N. Red dots, pelagic zooplankton; Brown dots, benthic amphipods; Light green dots, arctic cod; Orange dots, ringed seals; Dark green dots, seabirds (GLGU, glaucous gull; IVGU, ivory gull, NOFU, northern fulmar, BLGU, black-legged gull; BLKI, black-legged kittiwake; TBMU, thick-billed murre; DOVE, dovekie) (From CACAR II 2003: Biological Environment, Figure 3.3.19, page 54).**

16.17 RECOMMENDATIONS

The comparison of results from Henderson (1989) with ISQG and PEL values is compromised because they refer to different size fractions. Henderson (1989) analyzed the clay-size fraction but the ISQG and PEL are expressed in terms of whole, unfractionated sediment. In order to make legitimate comparisons, the measurements need to be expressed in the same units as the ISQG and PEL. This cannot be done on the basis of information available. Given the problem with mercury in arctic animals generally, it would be desirable to select an appropriate sub-set of sediment samples held by the Geological Survey and analyze them for mercury.

Hudson Bay is strongly influenced by inputs of freshwater. Data on contaminants in the water of Hudson Bay are very rare but Yates (1993) estimated that Hudson Bay supplies about as much of several metals (Mn, Fe, Co, Ni, Cu, Zn) to the Atlantic as does the Gulf of St. Lawrence. Additional future effort will be required to describe mass budgets of several key elements (notably Hg, Cd and synthetic organic compounds).

The large body of data produced by the Geological Survey of Canada and described briefly by Painter et al. (1994) is remarkable for its scope. From the maps included in this report, it is clear that a significant proportion of those data apply to areas draining into Hudson Bay or Foxe Basin. If the raw data are available, then further analysis of them would likely lead to additional insights about Hudson Bay sediments.

Data on mercury in marine fish and invertebrates from Hudson Bay are fragmentary. Levels are sometimes high enough to raise questions regarding subsistence consumption. There is evidence that hydroelectricity projects have exported mercury downstream to marine habitat and more of these projects can be anticipated in view of the projected shortages of certain fossil fuels in the coming decades. A systematic survey of mercury in marine invertebrates and fish will be required to determine the impacts of existing and future developments in the watershed.

There is the potential for impacts of regional climate warming in drainages to the west of Hudson Bay. This trend can result not only in habitat change but also in changing fluxes of materials to Hudson Bay. In the instance of mercury, for example, warming of whole permafrost-dominated basins to the west of Hudson Bay would be expected to result in increased erosion of particles and increased methylation and hence biological accumulation of mercury. This might be detected most readily by sedimentation studies in selected estuaries.

Organochlorine compounds differ somewhat from site to site even within the Hudson Bay/Foxe Basin/Hudson Strait area. With the exception of DDT, which seems to be declining at least in some species, temporal trends are still difficult to determine. With differences from one location to another, future work will have to be done on a site-by-site basis. Sentinel organisms and sites need to be selected for repeated monitoring over the coming years. Otherwise, even relatively large studies risk becoming too diffuse to detect temporal changes with high statistical confidence.

Levels of some organochlorines and mercury in some of the animals are high enough in some instances to pose a risk of biological injury. There is an almost complete lack of experimental work to find out whether existing levels are meaningful biologically. While this is understandable with some of the large species, toxicology experiments can and should be done with some of the smaller animals like fish and invertebrates, and with common laboratory surrogates for the large mammals.

Studies in areas outside Hudson Bay have revealed growing inputs of new stable chemicals like polybrominated diphenylethers (Figure 16-52). Future work on Hudson Bay biota should include assessment of these and other new chemicals.

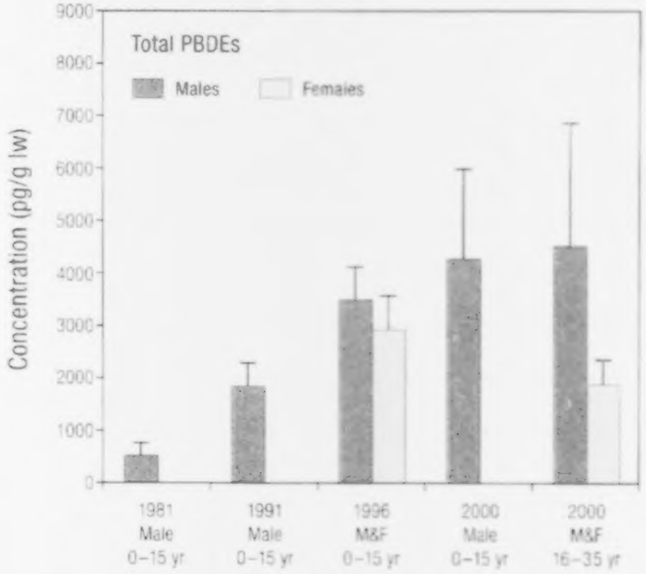

Figure 16-52. **Increasing concentrations of polybrominated diphenylethers (dibrominated to hepta-brominated congeners) in ringed seal blubber from Holman in the western Canadian Arctic. (From CACAR II 2003: Biological Environment, Figure 4.3.7, page 77).**

The watersheds draining to Hudson Bay are being changed by human activities, notably population growth and associated business activity, agriculture, hydroelectric development, and climate change. In addition to alterations in watersheds, there is direct loading to the water surface of Hudson Bay by materials dispersed via atmospheric circulation. With the relatively limited attention contaminants have been given in Hudson Bay, existing analyses and those done in the coming few years have 'benchmark' quality that will help to assess the magnitude and significance of future changes.

16.18 SUMMARY

Synthetic organochlorines and radionuclides produced by nuclear fission are two groups of contaminants found in the Hudson Bay marine ecosystem that result exclusively from human activities. They are products of 20th-century technology and have no natural sources or natural background concentrations. These compounds reach the Arctic by several means but one important pathway is via moving air masses. The have little or no history of use in the North but occur throughout the Arctic in air, water, sediment, and aquatic life.

Studies of the composition of the air from the Canadian North have consistently identified a wide range of synthetic organic compounds that originate thousands of km away. Organochlorine compounds differ somewhat from site to site even within the Hudson Bay/Foxe Basin/Hudson Strait area. Several contaminants move through food chains to become concentrated in animals at high trophic levels. With the exception of DDT, which seems to be declining in some species, temporal trends are still difficult to determine. With differences from one location to another, future work will have to be done on a site-by-site basis. Sentinel organisms and sites need to be selected for repeated monitoring over the coming years. Otherwise, even relatively large studies risk becoming too diffuse to detect temporal changes with high statistical confidence.

Few data exist describing organic contaminants in Hudson Bay sediments. But, high levels of both DDT (56 ng·g^{-1} OC) and PCBs (920 ng·g^{-1} OC) have been reported from eastern Hudson Bay relative to other Arctic locations.

Levels of both PCBs and HCHs in female ringed seals were quite similar across the range of Arctic locations sampled. The value for ΣPCB in seals from western Hudson Bay of about 700 ng·g^{-1} wet weight (ww) in 1998-2000 may be compared with a value of 2100 ng·g^{-1} ww for female seals from the same area in 1989-94. This implies a decrease in PCB contamination over the interval. The value for HCHs in blubber of seals from western Hudson Bay in 1998-2000 (about 100 ng·g^{-1} ww) was one of the lowest found. PCB levels in blubber of belugas from Hudson Bay were higher than those in ringed seals. The mean concentration in male belugas from western Hudson Bay in 1992-95 was about three times higher than it was in the seals.

Concentrations of several organochlorine compounds in fat of mature polar bears from the Churchill area have been measured several times over the period 1969-1998. Recent levels of ΣPCBs were under 3000 ng·g^{-1} ww and all the other organochlorines reported were lower yet. The most consistent change is the decline in ΣDDT over the period from about 850 ng·g^{-1} ww in 1968 to about 250 ng·g^{-1} ww in 1999. CACAR II (2003) authors speculated that this decline is not typical of other Arctic data and might have been related to cessation of spraying DDT for the control of forest insects in the Hudson Bay watershed. ΣCBz appears to have increased between 1969 and 1984 and to have declined continuously since then. Similarly, levels of σHCH have declined since 1984 but levels of ßHCH have not, with the result that the blend of the components ΣHCH has changed over the period. Similarly, PCBs have declined during the 1990s but with a change in the composition of the mixture of PCB congeners in the bears. The proportion of less chlorinated congeners has increased while the proportion of highly chlorinated congeners has fallen with the result that no long-term trend in ΣPCBs since 1968 is evident.

Studies in areas outside Hudson Bay have revealed growing inputs of new stable chemicals like polybrominated diphenylethers. Future work on Hudson Bay biota should include assessment of these and other new chemicals.

The source of anthropogenic cesium-137 in this area was atmospheric testing of nuclear bombs, most of which ended in 1963 by international agreement. Little information exists on radionuclides in the aquatic biota of Hudson Bay. Levels of cesium-137 in animals today will have fallen below the values recorded in the early 1980s because the half-life of cesium-137 is only 30 years and inputs of new Cs-137 have fallen dramatically. The natural radionuclides polonium-210, radium-226, thorium-230, thorium-232, uranium-234, and uranium-238 were measured in a series of surface sediment samples collected in 1995 near Rankin Inlet. The highest levels of these radionuclides usually were found closest to the community of Rankin Inlet.

Human activities may also redistribute naturally occurring elements, including toxic heavy metals and metal-like compounds (e.g., arsenic), to the Hudson Bay marine ecosystem. Their presence is not, in itself, evidence of human activity because many elements are present naturally in soils and sediments. However, human activities often move elements about in the environment in ways and at rates not found naturally. The questions that arise in cases of suspected contamination by elements are whether the amounts found exceed natural background amounts and what the sources might be. Among the more toxic elements are cadmium, copper, chromium, lead, mercury, and zinc and the metalloids arsenic and selenium. In view of the potential for these elements to produce biological harm, Canada has established Interim Sediment Quality Guidelines (ISQG) and Probable Effect Levels (PEL). These guidelines describe levels that should not be exceeded in freshwater and marine sediments in order to avoid biological impacts.

Chemical contaminants often become incorporated into aquatic sediments. Their horizontal and vertical distribution in the sediments provides a valuable record of where and when contamination has occurred. The Geological Survey of Canada (GSC) has collected seafloor sediments throughout Hudson Bay, using grab samplers. Henderson (1989) reported the data from these samples, which provide an overview of the surficial distribution of many important elements. These results cannot be compared directly with ISQG and PEL values because they refer only to the clay fraction and not in the unfractionated sediment, but the error is likely conservative since metals are usually more abundant in clay-sized particles than in larger particles. Vertical core samples of the bottom sediment have been used to examine the deposition history at a few locations.

The distribution of elements for which sediment quality guidelines have been established found little evidence of contamination. The highest concentrations of arsenic are mostly located in central Hudson Bay. The levels reported likely indicate a natural background for arsenic in fine sediment particles distributed by natural processes. Most of the sites with chromium over the PEL were offshore in southwest Hudson Bay, suggesting the possibility of chromium-enriched sediments originating from drainages entering Hudson Bay from the west. It is not known whether the existing levels in the sediment represent a risk to the biota of southwestern Hudson Bay. In general, the highest copper values were found off the west coast of Hudson Bay near the Churchill River. Copper enrichment has also been found in the sediment north of Arviat and between Chesterfield Inlet and Rankin Inlet. The distribution of copper may be explained by sediment transport offshore from Kivalliq. Only one site exceeded the PEL for lead. The core profile data suggest that Hudson Bay has received inputs of anthropogenic lead over the last century, probably from atmospheric fallout. There is no obvious clustering of high or low zinc values. Copper, lead, and zinc concentrations from bulk surficial sediment samples taken at five Ontario rivers, immediately before they enter Hudson Bay or James Bay, were well below those from the clay-size sediments from Hudson Bay.

No Interim Sediment Quality Guidelines have been established for aluminum, calcium, cobalt, iron, magnesium, manganese, molybdenum, nickel, or potassium. Several of these are major components of the earth's crust and the concept of ISQG does not apply. Others are trace metals for which ISQG values have not been established. These elements, along with oxygen, silicon and sodium, are the major components of the earth's crust. Conditions in the deeper areas of central Hudson Bay likely favour the diagenesis of manganese. The presence and levels of these elements in the sediments of Hudson Bay do not infer anthropogenic impacts.

Mercury is present naturally in the environment of Hudson Bay but is also added by a number of human activities. The GSC samples were not analyzed for mercury, so its distribution the surface sediment of the Hudson Bay seafloor is unknown. Given the problem with mercury in Arctic animals generally, an appropriate sub-set of sediment samples held by GSC should be analyzed for mercury. Mercury levels in core samples taken from southeast Hudson Bay and from VanVeen dredge samples taken near Rankin Inlet were well below the ISQG and PEL values. They do not portray a problem with mercury. Surveys of mercury in aquatic sediments have identified some high values in the drainages to the southwest of Hudson Bay. However, regional climate warming might result not only in habitat change but also in changing fluxes of materials to Hudson Bay. In the case of mercury, for example, warming of permafrost-dominated basins to the west of Hudson likely increases the erosion of particles and methylation of inorganic mercury, and hence biological accumulation of mercury. This might be detected most readily by sedimentation studies in selected estuaries.

Despite the low levels of mercury in the sediments, there is a persistent problem with accumulations of mercury in marine animals high in the food chains. Two guideline figures are used in efforts to limit human intake of mercury. Concentrations should not exceed 0.5 $\mu g \cdot g^{-1}$ (wet weight) in fish sold commercially in Canada, and levels should not exceed 0.2 $\mu g \cdot g^{-1}$ in fish used for subsistence.

So little is known about mercury levels in marine fish of Hudson Bay that the few scattered reports available do little more than establish the need for a systematic survey of levels of mercury in marine fish and their supporting food chains. Levels are sometimes high enough to raise questions regarding subsistence consumption. However, mercury levels in anadromous charr are considerably lower than those in predatory landlocked fishes, such as lake trout, implying that feeding at sea supplies less mercury than feeding in lakes. There is evidence that hydroelectricity projects on the La Grande River have exported mercury downstream to marine habitat. A systematic survey of mercury in marine invertebrates and fishes will be required to determine the impacts of existing and future developments in the watershed, and the effects of climatic warming in western Hudson Bay watersheds.

Of all northern animals, marine mammals generally have the highest levels of mercury. Most chemical residue analyses have been done with ringed seals, beluga whales, and polar bears. Ringed seal and beluga whale livers contain high levels of mercury but only a small proportion of it is present as neurotoxic methylmercury. Mercury levels seem to have increased since the mid- 1980s at Arviat and possibly at Sanikiluaq, although the latter collections were only four years apart. The whales harvested near Arviat summer downstream from the Churchill-Nelson hydroelectric development. The levels of mercury in the whales vary greatly among organs.

Since the whales' major intake of mercury is from dietary methylmercury, the presence of a high proportion of apparent HgSe in the liver may represent a metabolic detoxification mechanism to bind the mercury as an inert form and render it non-toxic or at least less toxic. The levels of mercury in beluga, narwhal and ringed seal livers consistently exceeded those in walrus. One might expect polar bears to contain higher amounts of mercury than their prey but this is not the case. This apparent discrepancy is explained by the fact that the bears eat only the blubber of the seals, not the protein-rich organs like muscle and liver where more mercury is found.

The data from sediments available to date do not suggest a contamination problem with cadmium. The value given for cadmium in liver of seals from Arviat was about 12 $\mu g \cdot g^{-1}$ ww. This appears to be below the threshold for biological effects, which is 20-200 $\mu g \cdot g^{-1}$ ww. A small proportion of the seals would reach or exceed the lowest part of the effects range.

Levels of some organochlorines and mercury in some of the animals are high enough in some instances to pose a risk of biological injury. There is an almost complete lack of experimental work to find out whether existing levels are meaningful biologically. While this is understandable with some of the large species, toxicology experiments can and should be done with some of the smaller animals like fish and invertebrates, and with common laboratory surrogates for the large mammals.

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17.0 CLIMATE CHANGE

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Table 17-1. Environmental changes observed in James Bay, Hudson Bay, and Hudson Strait by Inuit and Cree 17–10

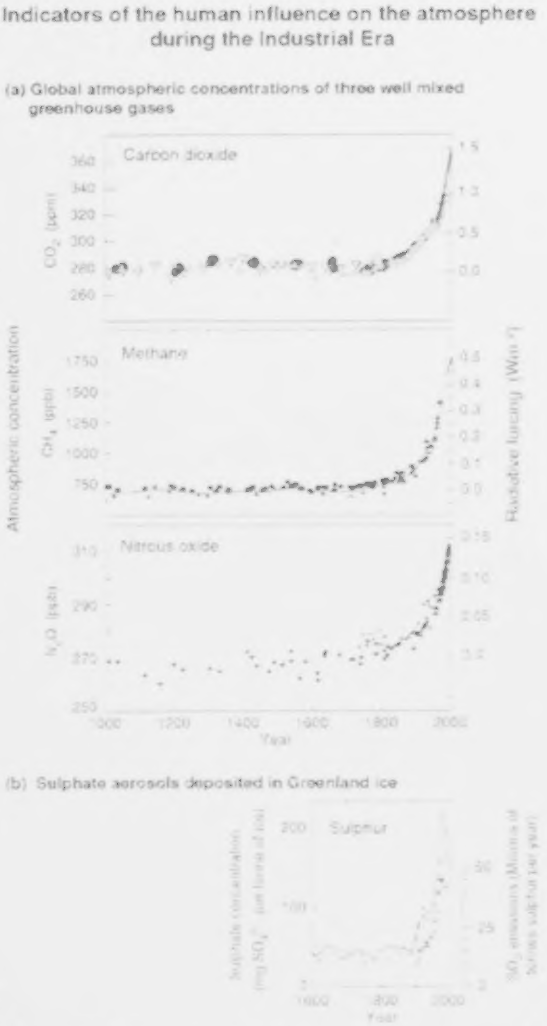
Natural large-scale climate shifts, or climate changes, such as those that resulted in past ice ages or warm interglacial periods, are driven by longterm alterations in the position of the Earth with respect to the Sun (Maxwell 1997). They can be reflected in changes in the composition of the Earth's atmosphere, particularly in greenhouse gases such as carbon dioxide and methane, which help to maintain surface temperatures in the range needed to support life. These gas concentrations are lowest during ice ages and highest during warm periods. This correlation is of concern because the atmospheric concentrations of these gases have increased sharply over the past 200 years, coincident with industrial development and the burning of fossil fuels (Figure 17-1). This increase has already affected the Earth's climate and this trend is expected to continue. Indeed, within the next century the atmospheric concentration of carbon dioxide may double.

The key temperature, hydrological, and storm-related indicators of global climate change are illustrated in Figure 17-2 and Figure 17-3, which also describe the degree of scientific certainty that the observed effects are real. Their direction and magnitude vary within and among regions.

The following sections examine current evidence for climate change in the Hudson Bay region, predictions for future climate change, and the effects these predicted changes might have on the marine ecosystem.

17.1 EVIDENCE FOR CLIMATE CHANGE

There is persuasive evidence that the climate is changing, in Canada and around the globe (e.g., McDonald et al. 1997; Zhang et al. 2000; Bonsal et al. 2001; IPCC 2001; Whitfield et al. 2002; Macdonald, 2003b), but statistical evidence for climate change in the Hudson Bay basin is limited (Cohen et al. 1994; Gagnon and Gough 2002). This does not mean that the marine ecosystem is not affected, rather that there have been few regional studies and that the wide variability of temperature and precipitation over time and space within the region makes relatively subtle long-term trends difficult to detect. Regional and national studies often aggregate the climate data over a year or a large geographical area. In an area like Hudson Bay, where the bay affects climate differently in the east and west, north and south, this can obscure local climatic trends by effectively increasing the range of natural variability of the region as a whole.



Indicators of the human influence on the atmosphere during the Industrial Era

(a) Global atmospheric concentrations of three well mixed greenhouse gases

(b) Sulphate aerosols deposited in Greenland ice

Figure 17-1. (a) Global trends in the concentration of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) over the past 1000 years. The estimated positive radiative forcing of the climate system from these gases is shown on the right-hand scale. (b) The influence of industrial emissions on atmospheric sulphate concentrations, which produce negative radiative forcing (from IPCC 2001).

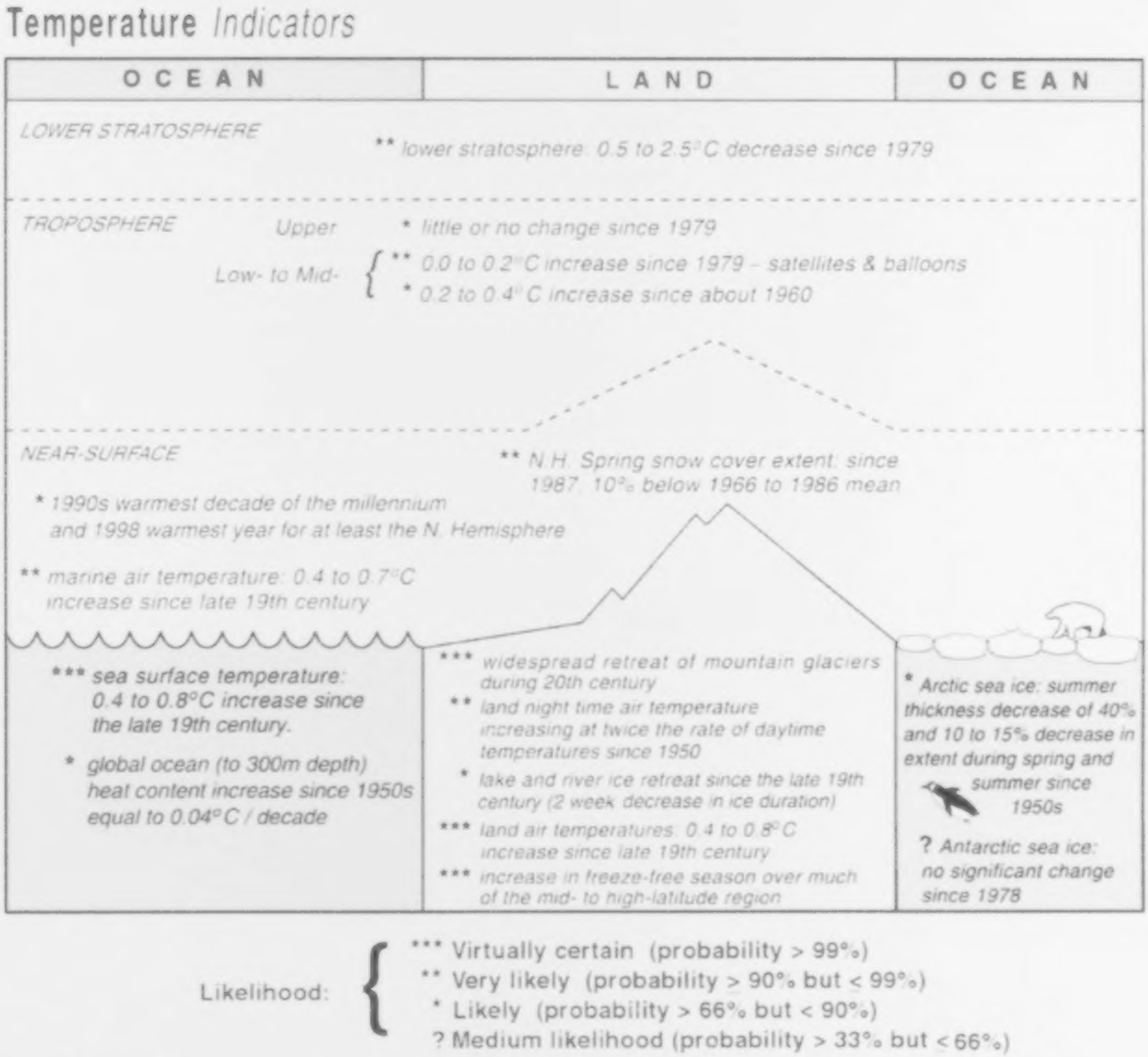
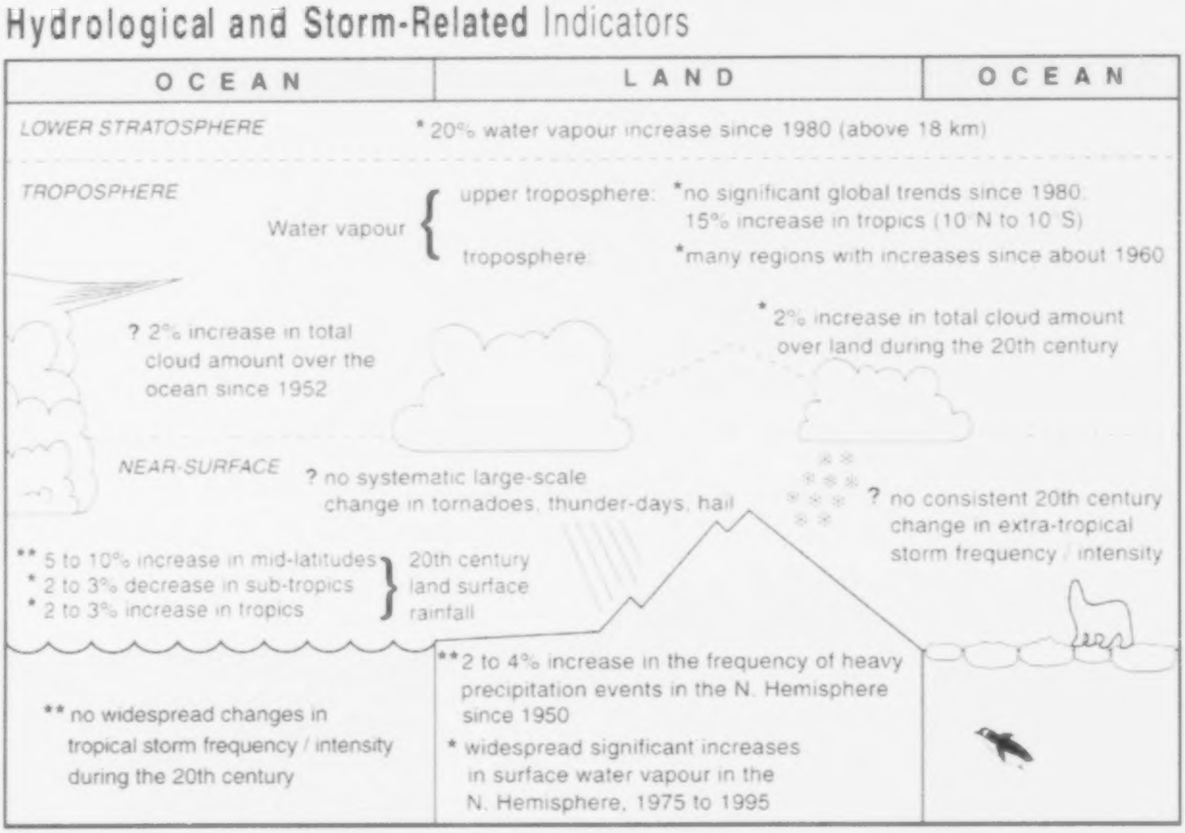

Temperature Indicators
OCEAN
LAND
OCEAN
LOWER STRATOSPHERE
** lower stratosphere: 0.5 to 2.5°C decrease since 1979
TROPOSPHERE
Upper
* little or no change since 1979
Low- to Mid-
** 0.0 to 0.2°C increase since 1979 – satellites & balloons
* 0.2 to 0.4°C increase since about 1960
NEAR-SURFACE
** N.H. Spring snow cover extent: since 1987, 10% below 1966 to 1986 mean
* 1990s warmest decade of the millennium and 1998 warmest year for at least the N. Hemisphere
** marine air temperature: 0.4 to 0.7°C increase since late 19th century
*** sea surface temperature: 0.4 to 0.8°C increase since the late 19th century.
* global ocean (to 300m depth) heat content increase since 1950s equal to 0.04°C / decade
*** widespread retreat of mountain glaciers during 20th century
** land night time air temperature increasing at twice the rate of daytime temperatures since 1950
* lake and river ice retreat since the late 19th century (2 week decrease in ice duration)
*** land air temperatures: 0.4 to 0.8°C increase since late 19th century
*** increase in freeze-free season over much of the mid- to high-latitude region
* Arctic sea ice: summer thickness decrease of 40% and 10 to 15% decrease in extent during spring and summer since 1950s
? Antarctic sea ice: no significant change since 1978
Likelihood:
*** Virtually certain (probability > 99%)
** Very likely (probability > 90% but < 99%)
* Likely (probability > 66% but < 90%)
? Medium likelihood (probability > 33% but < 66%)

Figure 17-2. **Temperature indicators of global climate change (from IPCC 2001).**

Cohen et al. (1994) found evidence of warming in western Hudson Bay and cooling in the east, and of earlier ice-breakup at lakes southwest of Hudson Bay. When all the stations were combined, no trend in annual temperature was identified. They also presented evidence of increasing annual precipitation with trends toward greater precipitation in spring, summer, and autumn. None of these trends was analysed for statistical significance. The form of this precipitation, rain or snow, is vitally important as early spring rains can cause the collapse of seal breeding lairs (Stirling and Smith 2004). Other studies have analysed the temperature and precipitation records of Canadian stations during the twentieth century but have not found statistically significant trends in the Hudson Bay region (e.g., Zhang et al. 2000; Bonsal et al. 2001; Whitfield et al. 2002, 2004).

Streamflow is a useful indicator of climate change because, at the outlet of a basin, it integrates the effects on precipitation and evapotranspiration over the whole basin (Zhang et al. 2001). Changing streamflow into Hudson Bay provides some evidence for climate change but it is not coherent in time or space. Gagnon and


Hydrological and Storm-Related Indicators
OCEAN
LAND
OCEAN
LOWER STRATOSPHERE
* 20% water vapour increase since 1980 (above 18 km)
TROPOSPHERE
Water vapour
upper troposphere: *no significant global trends since 1980; 15% increase in tropics (10°N to 10°S)
troposphere: *many regions with increases since about 1960
? 2% increase in total cloud amount over the ocean since 1952
* 2% increase in total cloud amount over land during the 20th century
NEAR-SURFACE
? no systematic large-scale change in tornadoes, thunder-days, hail
? no consistent 20th century change in extra-tropical storm frequency / intensity
** 5 to 10% increase in mid-latitudes
* 2 to 3% decrease in sub-tropics
* 2 to 3% increase in tropics
20th century land surface rainfall
** no widespread changes in tropical storm frequency / intensity during the 20th century
** 2 to 4% increase in the frequency of heavy precipitation events in the N. Hemisphere since 1950
* widespread significant increases in surface water vapour in the N. Hemisphere, 1975 to 1995

Likelihood:
- *** Virtually certain (probability > 99%)
- ** Very likely (probability > 90% but ≤ 99%)
- * Likely (probability > 66% but < 90%)
- ? Medium likelihood (probability > 33% but < 66%)

Figure 17-3. Hydrological and storm-related indicators of global climate change (from IPCC 2001).

Gough (2002) tested for relationships between streamflow, temperature, and precipitation over time at ten rivers that flow into Hudson Bay. None of them had been modified by hydroelectric development and all had at least 30 years of monthly flow records. The pattern of change they observed in streamflow was not consistent across the Hudson Bay basin but was correlated with changes in temperature and precipitation. A statistically significant spring warming trend was identified in a region that extends from Manitoba to Quebec. Within this region the Missinaibi, Island Lake, and De Pontois rivers showed a shift towards an earlier peak in spring discharge. In northwestern Hudson Bay, precipitation had increased significantly in all seasons such that the discharge of the Kazan River had increased in most months and on a yearly average. Zhang et al. (2001) found similar results for this region. In contrast, a decrease in river discharge was detected in central Manitoba, because of warmer temperatures and less rainfall. On the east side of Hudson Bay, statistically significant streamflow trends were detected for individual months, but the patterns were not coherent in time or space. The effects of climate change on streamflow in the Hudson Bay region are difficult to predict as they are not spatially uniform and are obscured when the Hudson Bay basin is treated as a single large region.

Changes in the sea level of Hudson Bay may provide evidence of global climate change. The sea level at Churchill has been monitored virtually continuously since 1940 (Tushingham 1992). It is the cumulative result of daily tidal variations, short term changes in river discharge and wind forcing, and the longterm effects of isostatic rebound, lithospheric adjustment since the last ice age, and changes in ocean volume due to land-based ice melt and thermal expansion (Gough and Robinson 2000). At Churchill, 43% of the monthly variation in sea level can be explained by local discharge from the Churchill River. The level is also affected in autumn by runoff from elsewhere in the basin, particularly James Bay. The amplitude of these seasonal changes increased in 1975 when flow was diverted from the Churchill River into the Nelson River, leading to lower pre-spring sea levels. Longterm variations in sea level may be related to thermal expansion or contraction of the oceans. To date there is no evidence that climate change has affected the sea level of Hudson Bay.

The most telling evidence of climate change in Hudson Bay is in the ice cover record (Chapman and Walsh 1993; Parkinson 2000a+b; Agnew et al. 2001; Parkinson and Cavelieri 2002; Gough et al. 2004). Satellite passive-microwave data have been used to calculate sea-ice extents over the period 1979-99 for Hudson Bay, which for the purposes of that study also included Foxe Basin and Hudson Strait (Parkinson and Cavelieri 2002). Over the 21-year period the yearly-average extent of sea ice concentrations with over 15% coverage was 798,000 km^2 with a decreasing trend of -4,300 ± 1,400 km^2·a^{-1} (99%CI; P=0.01). The extent of the ice cover has been decreasing in June and July, and in November and December, indicating that the ice is melting earlier in the spring and forming later in the fall (Figure 17-4 and Figure 17-5). Most of the decline in the yearly averaged ice cover from 1979-96 occurred in the 1990's (Figure 17-6) (Parkinson 2000b). Over this 18-year period, the length of the sea ice season decreased in northwest Hudson Bay and along the southern coasts Hudson Bay and James Bay, but increased in east central Hudson Bay and near the Belcher Islands and Akimiski Island (Figure 17-7). Gough et al. (2004) found that the onset of breakup in southwestern Hudson Bay advanced by 3 days per decade over the period 1971 to 2003. There is wide variation in ice cover among years both seasonally, during breakup and freeze-up, and overall. While the satellite data reveal changes in the extent of the ice cover, they are not useful for determining changes in ice thickness, which is an important determinant of the volume of freshwater that is sequestered each year during ice formation and released in the spring.

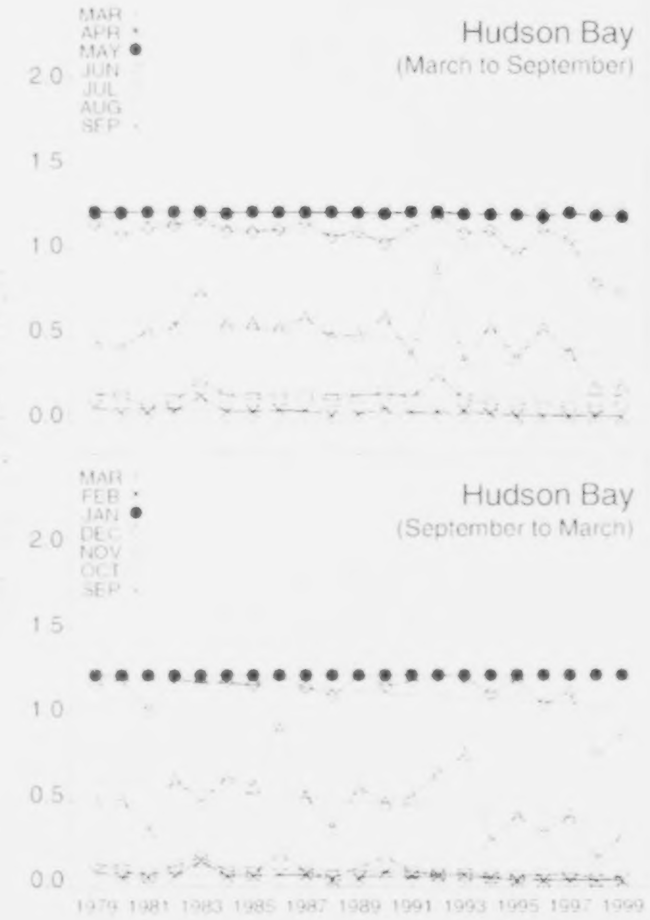


Figure 17-4. **Time series of monthly sea-ice extents, arranged by month, the for Hudson Bay-James Bay-Foxe Basin-Hudson Strait area (from Parkinson and Cavelieri 2002:443). The top plot presents results from March-September, the bottom plot presents results for September-March. Lines of linear least-squares fit are included for each month.**

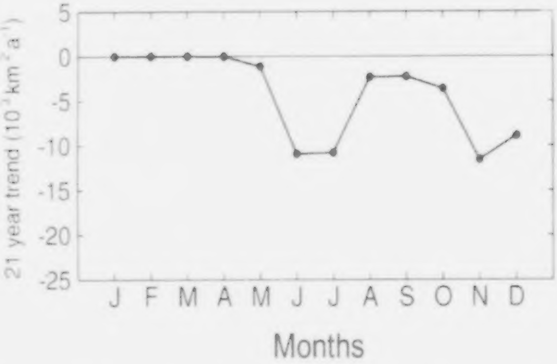


Figure 17-5. Trends, by month, in the sea-ice extent of the Hudson Bay-James Bay-Foxe Basin-Hudson Strait area calculated over the 21 years 1979-99 (from Parkinson and Cavalieri 2002:445). The trend values are the slopes of the lines of linear least-squares fit through the appropiate 21 monthly-average ice extents.

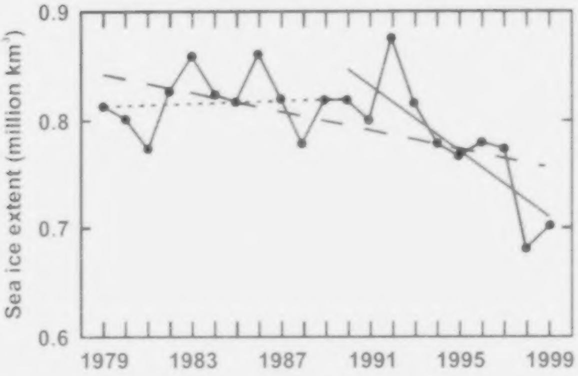
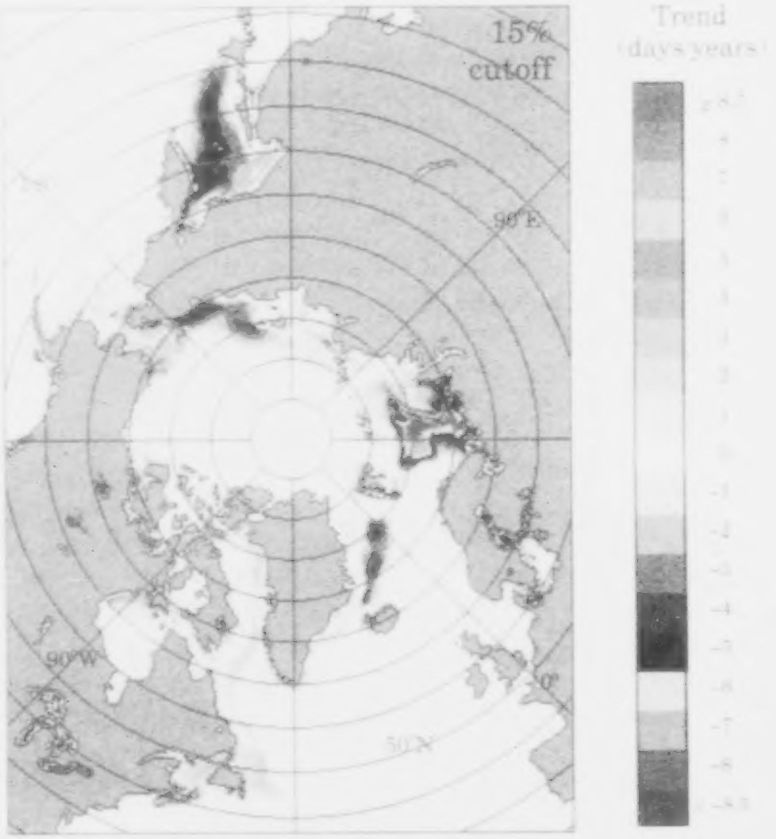


Figure 17-6. Times series of the yearly averaged extent of sea ice in Hudson Bay-James Bay-Foxe Basin-Hudson Strait from 1979-99 (from Parkinson 2000a:6). Lines of linear least squares fit are plotted for the full period (dashed) and for the 1979-90 (dotted) and 1990-99 (solid) subperiods.

Figure 17-7.

Trends in the length of the sea ice season from 1979 through 1996, calculated at each 10 km^2 grid cell as the slope of the line of linear least squares fit through the 18 years of season length data (from Parkinson 2000b:353). The length of the sea ice season was defined as the number of days with calculated ice concentration =15%. Ice concentrations were derived from satellite data.



Climate change may also be affecting the polar bears in Hudson Bay and James Bay. As the top carnivores at the southern limits of their distribution, they are the "canaries in the coal mine" for regional climate change (Stirling and Derocher 1993). They require ice as a platform from which to hunt seals, as habitat on which to seek mates and breed, as a surface on which to travel long distances, and sometimes for maternity denning (Stirling and Derocher 1993; Stirling et al. 2004). The surface area of the seasonal ice cover determines the extent and quality of the bear's feeding habitat, and its duration determines how long they are able to feed and build up their fat stores. These stores must sustain them and their cubs from the time the ice melts and they are forced ashore, until it reforms in the fall and they can move offshore again to hunt—a period of about 4 months. Some bears eat a variety of vegetable and animal foods while on shore but these foods are not sufficient to sustain them year-round. Their dependence on ice cover makes polar bears very vulnerable to changes in its quality, distribution, and duration. Recent declines in body condition, reproductive rates, and cub survival (Figure 17-8), and an increase in polar bear-human interactions, suggest that the bears in western Hudson Bay are under increasing nutritional stress (Stirling et al. 1999; Calvert et al. 2001). These changes have been correlated with earlier breakup and later freeze-up that have prolonged the ice-free period, and thereby reduced feeding opportunities for the bears while increasing the length of their fast (Figure 17-9 and Figure 17-10). They likely are early impacts of climate change, but other factors have not been ruled out. Similar changes have not been observed in the Southern Hudson Bay Population that summers along the Ontario coast, where ice breaks up later (Obbard and Taylor unpubl. data cited in Calvert et al. 2001).

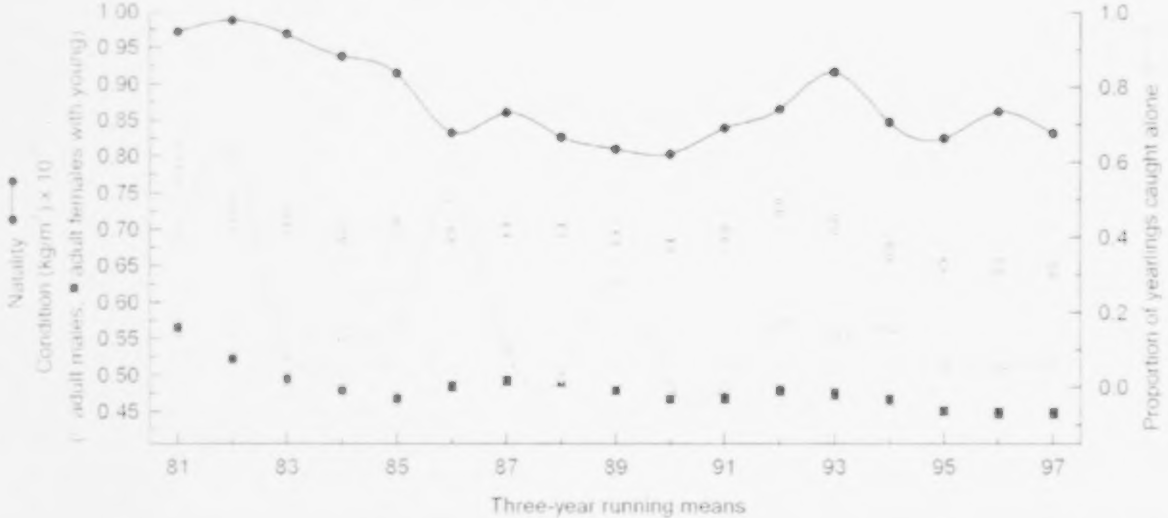


Figure 17-8. **Trends in natality and condition of adult male and female polar bears, expressed as three-year running means, and the proportion of yearlings that were alone when captured in the fall (Stirling et al. 1999:302).**

Ramsay and Stirling (1990) also documented a northward shift in the location of polar bear winter maternity dens in the area south of Cape Churchill, between 1970-76 and 1980-84. The reasons for this shift are not clear but the authors have suggested that they too might be related to changes in the sea ice.

Changes in the diet of thick-billed murre chicks at Coats Island suggests that the character of the fish community in northern Hudson Bay switched from Arctic to Subarctic circa 1997 (Gaston et al. 2003). The occurrence of Arctic cod, and benthic sculpins and zoarcids in their diet decreased, while that of capelin and sandlance increased (Figure 17-11). These changes were associated with a halving of the mid-July ice cover in Evans Strait over the period 1981-99, and may reflect the effects of a general warming of Hudson Bay waters on the relative abundance of these fish species. A reduction in prey availability, rather than abundance, cannot be

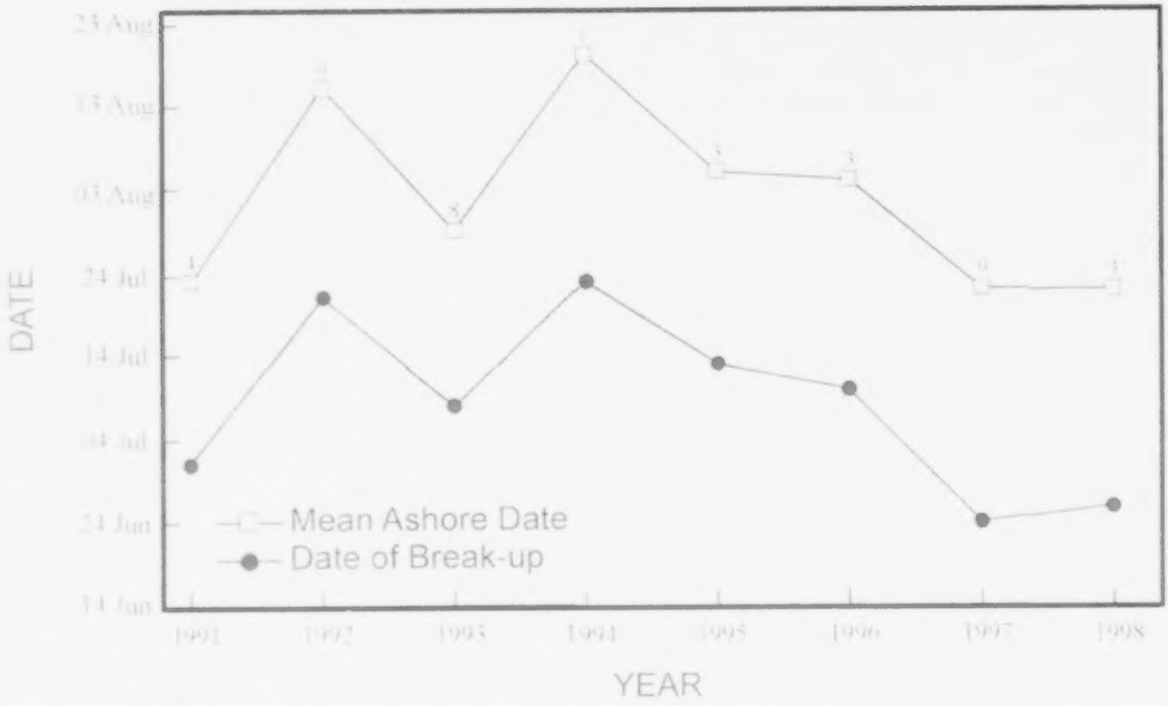


Figure 17-9. Mean date of ice breakup in the area of Hudson Bay where female polar bears with satellite collars spent at least 90% of their time each year (1991-98) and the mean dates the bears came ashore in those years (numbers above line = sample size) (from Stirling et al. 1999:299).

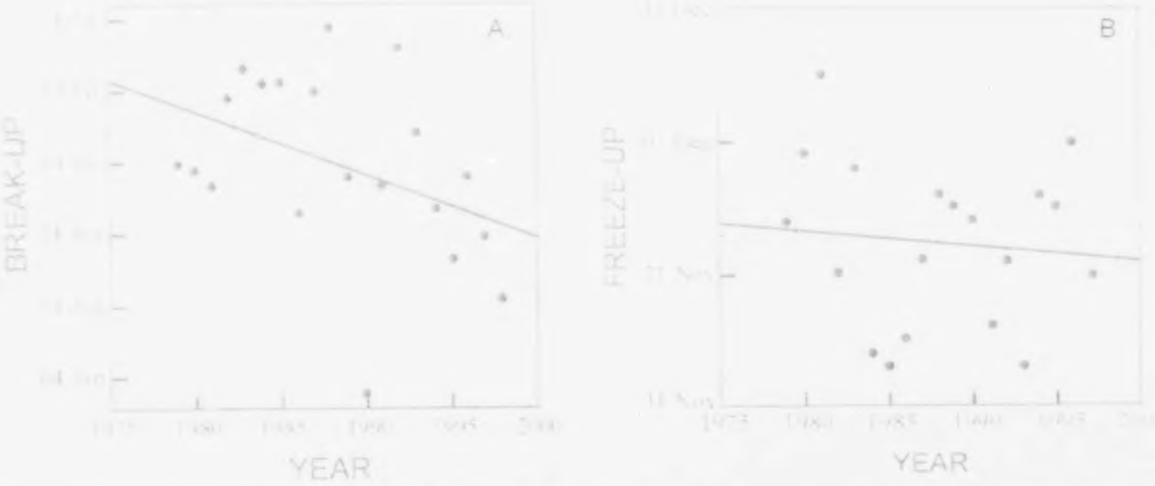


Figure 17-10. Dates of (A) breakup and (B) freeze-up of sea ice in western Hudson Bay (1979-98) (from Stirling et al. 1999:299).

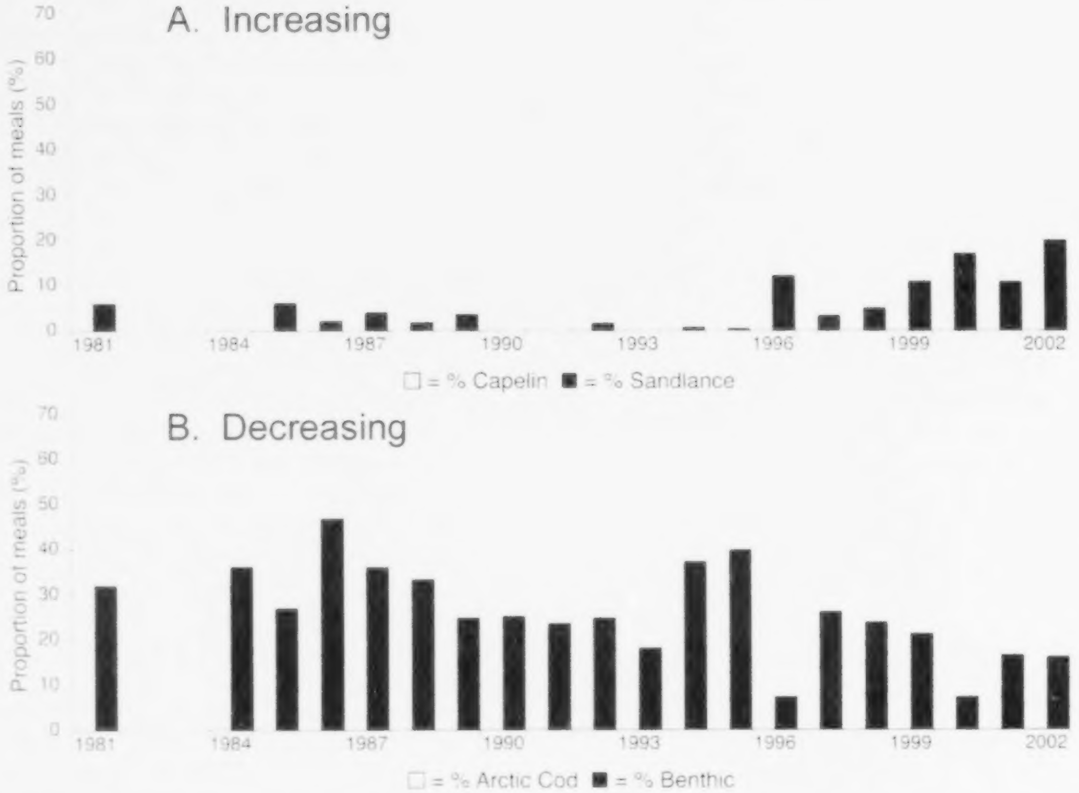


Figure 17-11. Proportion of different fish taxa in the diet of thick-billed murre chicks at Coats Island since 1981: A) increasing (capelin and sandlance); B) decreasing (Arctic cod and benthic genera = sculpins and zoarcids) (from Gaston et al. 2003:230).

ruled out as the cause of this change but two lines of evidence indicate otherwise. First, murres in the High Arctic that feed their chicks mainly on Arctic cod do so well after the ice goes, suggesting that these fish should be available to the murres in Hudson Bay despite the increase in open water. Second, 2002 was a late ice year and the proportion of cod in the diet remained low, suggesting that the late breakup does not make cod more available. Concident with these changes, in 2001 and 2002, the razorbill (*Alca torda*) was showing signs of colonizing Coats Island (Woo and Gaston cited in Gaston et al. 2003). This Atlantic seabird feeds heavily on capelin and sandlance, and had not previously been reported from Hudson Bay.

Inuit and Cree in Hudson Bay and James Bay have observed a number of environmental changes, particularly related to weather, that are consistent with the scientific observations of climate change (Table 17-1)(McDonald et al. 1997). They suggest that the climate is cooling in the east and warming in the west and northwest. Changes in the migratory timing and patterns of geese may also be related in part to climate change. Traditional knowledge can complement scientific approaches to understanding climate in Arctic Canada by providing local expertise, climatic history and baseline data, and local monitoring (Reidlinger and Berkes 2001; see also Duerden and Kuhn 1998). It also provides information that is useful for framing studies and interpreting data.

Table 17-1. **Environmental changes observed in James Bay, Hudson Bay, and Hudson Strait by Inuit and Cree (modified from McDonald et al. 1997).**

	Eastern James Bay	Eastern Hudson Bay	Hudson Strait	Northwestern Hudson Bay	Western Hudson Bay	Western James Bay
Weather	• shorter spring and fall seasons; • greater variability in fall; • colder winters in reservoir areas; • increased snowfall.	• cold weather persists into spring; • snow melts later • spring and summer cooling trend • less rain, fewer thunder-storms	• greater variability • less predictable • cooling trend; • new snowfall cycle; • longer winters, snow melts later; • less rainfall.	• greater variability; • warmer, shorter winters; • snow falls and melts earlier; • cool summers in early 1990s.	• longer winters; colder springs; snow melts faster	• shorter and warmer winters; • spring wind shifts several times a day
Atmosphere	• change in sky colour	• change in sky colour • sun's heat blocked by haze.	• change in sky colour.	• change in sky colour	• change in sky colour	• change in sky colour.
Sea Level	• salinity changing along north-east coast ; • more freshwater ice in the bay • less solid in La Grande River area • freezes later, breaks earlier.	• freezes faster; • solid ice cover is larger and thicker; • fewer polynyas; • floe edge melts before breaking up.	• freezes faster; • poorer quality landfast ice extends farther offshore; • polynyas freeze; • floe edge melts before breaking up.			
Currents	• weaker in Eastmain area, swifter and less predictable north of La Grande River	• weakening currents	• weakening currents	• weaker currents in Roes Welcome Sound		
Rivers	• seasonal reversal in levels and flow; • decline in water quality; • unstable ice conditions on La Grande River: freezes later, breaks earlier; • vegetation dying along diverted rivers	• decreased water levels and river flow.	• decreased water levels and river flow	• decreased water levels and river flow	• seasonal reversal in water levels and flow ; • increased salinity, erosion and sediment in Nelson River; • decline in water quality.	• decreased water levels and river flow in southern James Bay rivers; • increased erosion and mud slides.
Canada and Snow Geese	• coastal and inland habitat changes; • coastal flyways have shifted eastward; • fewer harvested in spring and fall; • large flocks of non-nesting/ moulting geese along coastal flyway.	• smaller flocks of Canada geese arrive in Belcher Islands since 1984; • more non-nesting/moulting geese in Belcher and Long islands.	• new snow goose migration routes; • more moulting snow geese; • Canada geese no longer nest in Soper River area.	• more Canada geese in Repulse Bay area during summers of 1992 and 1993.	• more snow geese migrating to and from the west; • habitat changes and Marsh Point staging area; • earlier and shorter fall migration.	• habitat changes in Moose Factory area; • more snow geese flying in from the west; • Canada geese arrive from the north first part of June; • Change in fall migration patterns
Beluga whale	• fewer	• fewer along coast; • moved to and travelling in currents farther offshore	• fewer in Salluit area	• fewer in Repulse Bay and Arviat area	• more in Fort Severn and Winisk estuaries; • fewer in Nelsen River estuary	
Fish	• mercury contamination; • loss of adequate habitat for several species, e.g., whitefish; • morphological changes in sturgeon.	• fewer Arctic char and Arctic cod in Inukjuak area		• fewer Arctic cod in near-shore areas; • Arctic cod no longer found in near-shore areas off Cape Smith and Repulse Bay.	• mercury contamination; • loss of habitat including spawning grounds; • change in taste of fish: some are inedible	• morphological changes in sturgeon; • dried river channels

17.2 CLIMATE CHANGE PREDICTIONS

Many scientists agree that there is a high probability of global warming during the next century. They are less certain about its causative factors, rate, extent, and regional effects given the complexity of the climate system and limited understanding of the crucial role played by the world's oceans. Improving our ability to predict these effects has become a research priority in Canada and elsewhere (e.g., Cohen et al. 1994; Hansell et al. 1998; Curry 2004).

While greenhouse warming is a relatively gradual process (>100 y), oceanographers have cautioned that it may have a destabilizing effect on world ocean circulation that could lead to abrupt (<10 y) regional cooling (Schmitt 2000; Gagosian 2003; Curry 2004). These sorts of non-linear threshold effects in environmental conditions may become more evident in the event of climate change (Woo et al. 1992; Jefferies et al. 1995; Schindler 2001). They can be directly or inversely related to the climate signal and, because they are difficult to predict given the complexity of feedback, are a significant source of uncertainty in modelling predictions. Rapid habitat destruction (desertification, trophic cascades) by goose populations along the Hudson By coast is one example of a threshold response triggered by weather (Jefferies et al. 1995).

Elaborate computer models have been developed to improve understanding of how the climate may respond to increases in greenhouse gas concentrations. These "general circulation models or GCMs" often simulate the type of climate that might exist if global concentrations of carbon dioxide were twice their pre-industrial levels. They use mathematical equations to represent physical processes of the climate system—particularly those involving radiation, heat and motion and the water cycle; and to calculate the interactions between these processes. Strictly speaking, they are not predictive models but rather a means of determining the sensitivity of the climate system to a change in one of its key elements (Cohen et al. 1994). In spite of their sophistication, they can only approximate reality given the complexity of the climate system and current understanding of climatic processes. They do, however, offer some predictive value and are the only practical and timely means of investigating the complete climate system and its response to the forces that affect it.

While sometimes disagreeing about the details, all of these models predict that the Earth would be warmer on average if the concentration of atmospheric carbon dioxide doubles, more so near the poles, and that it would experience overall increases in both evaporation and precipitation (Cohen et al. 1994; Maxwell 1997). They predict warming over much of western and northern Canada, but sometimes disagree on the location and magnitude of areas of surface temperature or precipitation change, particularly in eastern Canada. Warming is predicted to be greater over land than sea.

One weakness in GCMs is that few consider the effects of changes in atmospheric aerosol content (Maxwell 1997). Aerosols from atmospheric pollution can affect incoming solar radiation directly by scattering light back into space, and indirectly by promoting cloud formation and altering the chemical, thermodynamic, and optical properties of clouds. Studies are underway at Churchill, and across Canada, to gather data on spatio-temporal changes in Arctic aerosols to improve understanding of how they influence global climate and to improve the predictive ability of future climate models (Bokoye et al. 2002).

Another important weakness of climate models is their limited ability to simulate oceanographic processes, particularly those related to spatial variations in temperature and salinity (Schmitt 2000; Curry et al. 2003; Gagosian 2003). Like atmospheric winds, ocean currents circulate around the globe distributing heat. Changes to either circulation can have far-reaching climatic effects. The ocean currents move slowly but have a much greater heat capacity than the atmosphere (e.g., El Nino). When the saline surface water in the North Atlantic flows northward it loses heat to the atmosphere and cools until it can become dense enough to sink to the bottom. This makes room for more warm water to move north for cooling. If too much fresh water were to enter the North Atlantic its surface waters would no longer sink when cooled, and the flow of warm water from the Gulf

Stream could slow and perhaps stop (Aagaard and Carmack 1989; Curry et al. 2003). This might elicit a non-linear threshold response and cause an abrupt (< 10 y) climate change that would disrupt the hydrological cyle and partially or totally offset the effects of global warming in the North Atlantic region, a concern that has been identified for urgent study (e.g., Schmitt 2000; Curry et al. 2003; Gagosian 2003; Curry 2004). Whether, or how, this might affect the Hudson Bay marine ecosystem is unknown.

Climate models are not infallible. They are a respository for what we think we know (Schmitt 2000), and their response to different change scenarios relies on the judicious choice of model parameters. Gough (2001) demonstrated this in a study of the effects of climate change on sea ice in Hudson Bay. The model he used would reproduce the current climatology of the sea ice using many different pairs of values for the thermal conductivity of sea ice and thermal diffusivity of water. However, the ice thickness it predicted under a 3°C warming scenario varied widely for the different pairs, illustrating the precarious nature of modelling the climate system. The same is true of the choice of models. Gough and Wolfe (2001) compared the predicted impacts of doubling CO_2 on the Hudson Bay region, using a second generation of the Canadian general circulation model (GCMII) and the Canadian first-generation coupled general circulation model (CGCM I). The former represented the ocean as a simple two-layer slab ocean 50 m thick and predicted that the ice platform would remain in Hudson Bay; the latter used an ocean general circulation model and predicted its virtual disappearance. Clearly, the results of these models must be used with caution when their parameters produce such strikingly different results for an aspect of the marine ecosystem as vital as sea ice.

Work is under way to improve the predictive ability of these climate models for Hudson Bay (Wang et al. 1994a+b; Gachon et al. 2002, 2003; Senneville et al. 2002; Gachon and Saucier 2003; Saucier et al. 2004). It includes in particular the development of a model that more accurately represents the regional oceanography year-round. Embedding such a model into a larger scale climate model should improve predictive ability. However, improvements are also needed to the atmospheric model, particularly with respect to low-level atmospheric fields (e.g., lower winds and higher temperature) (Senneville et al. 2002). Because models are only as good as the information upon which they are based, a great deal of basic research is needed to improve understanding of the regional oceanography. Validation data sets are crucial, and coherent time series must be collected for a variety of locations.

17.2.1 Temperature

The global climate model (GCM) developed by the Canadian Centre for Climate Modelling and Analysis (CCC92) predicts a winter warming of up to 10°C and summer warming of 1-2°C by 2100 in central Hudson Bay (Maxwell 1997; Figure 17-12). Along the coasts, this increase is greater in winter (6-9°C) and than in summer (2-5°C). These warmer temperatures will melt permafrost and sea ice.

Various models predict that the area of discontinuous permafrost will eventually be halved and the boundary between continuous and discontinuous permafrost will shift hundreds of kilometres northward (Figure 17-13) (Woo et al. 1992; Maxwell 1997; Gough and Leung 2002). The timeframe for this change is uncertain but permafrost melting will lag behind surface air temperature changes (Smith 1989). Vegetation cover, soil properties, and snow cover will affect the rate and extent of changes in the permafrost. In the discontinuous zone, the depth of the active layer of soil may double. This may increase coastal erosion and the frequency of landslides and lead to pronounced thermocarst topography.

Soil processes will be affected strongly by the predicted increases in temperature and moisture (Maxwell 1997). The depth of the active layer will increase as permafrost thaws and nutrient availability should increase as the conditions for microbial decomposition of organic matter improve. Arctic tundra communities will respond with a shift toward larger shrub species that are more tolerant of moisture, and away from non-vascular plants and soil-insulating mosses (Figure 17-14). This will eventually lead to a northward shift of the treeline--which is closely related to the position of the 10°C mean July isotherm (see also Timoney et al. 1992), by up to 750 km in Kivalliq.

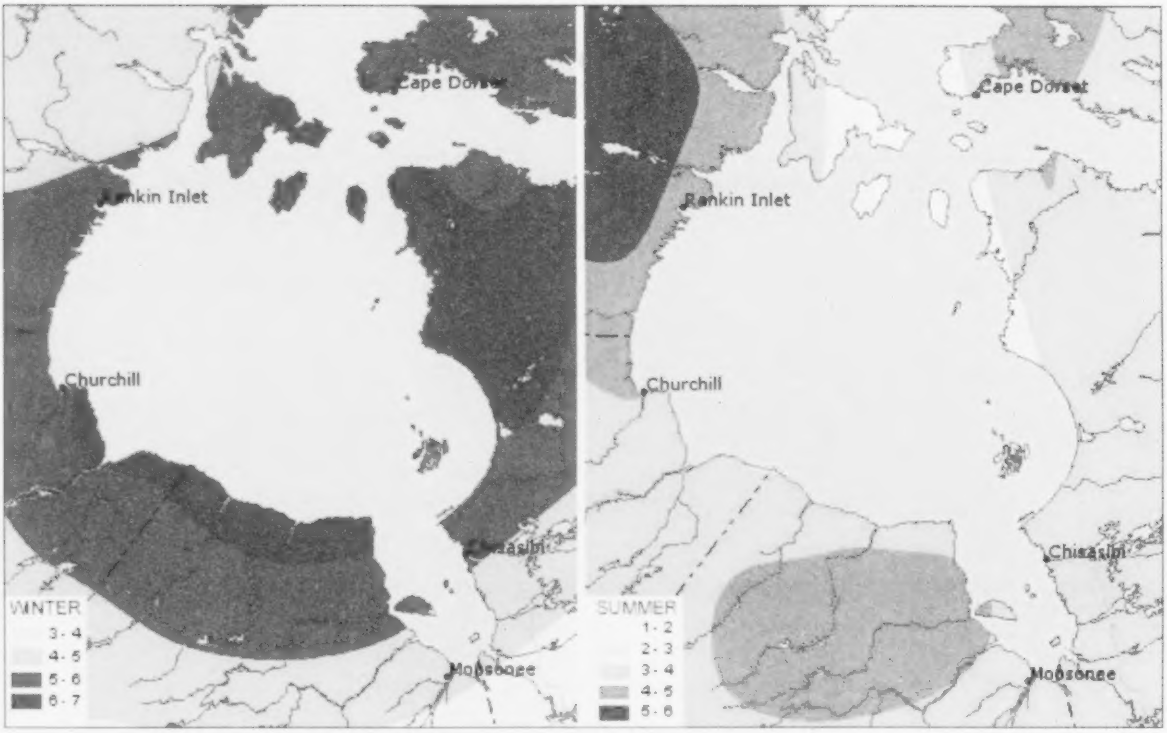


Figure 17-12. Change (°C) projected by the CCCma model in winter (December-February) and summer (June-August) air temperature from the reference period (1961-1990) to the middle of the current century (2040-2064) (from National Atlas of Canada 6th edn 2003c).

The Arctic Tundra biome may shrink until it is confined largely to the Arctic Islands. And, infilling by the taiga biome may not keep pace with the very rapid speed at which climatic warming is expected to occur. Within the existing treeline, the species composition of the forests is likely to change. Entire forest types may disappear, leading to new assemblages of species and ecosystems. The incidence of forest fires may increase and insect pests may move northward, reducing the yield of northern forests (Maxwell 1997). Timoney et al. (1992) provide a useful baseline for the location and composition of the treeline in Nunavut and the Northwest Territories against which change can be measured.

The subarctic peatlands south of Hudson Bay require a high, stable water table. They may be extremely vulnerable to climate change if warmer temperatures thaw the permafrost and affect their hydrology through changes in surface elevation, drainage, or flooding (Maxwell 1997).

Recent studies suggest that ice cover in Hudson Bay and James Bay will be reduced by climate warming but do not agree on the extent of the reduction. Global Climate Model results vary widely depending upon modelling parameters; some suggest that Hudson Bay may become ice free in winter (Cohen et al. 1994; Gough and Wolfe 2001). A three-dimensional coupled ice-ocean model also shows large reductions in the winter ice volume with climate warming (Saucier and Dionne 1998). It suggests that a simple 2°C increase in air temperature might reduce the sea ice produced in Hudson Bay by 20%, increase summer sea surface temperature by 4°C, and cause a two-week advance of breakup and delay of freezup. A comparison of sea ice concentration to melting degree day data suggests that warming of 1°C could advance ice break-up as much as two weeks in parts of the Bay (Etkin 1991). Because melting sea ice contributes more fresh water to Hudson Bay than does runoff, any change in ice cover will alter the freshwater budget (see Section 4.3), with wide ranging effects on the oceanography and ecology (see also Chapter 5 and Section 15.1).

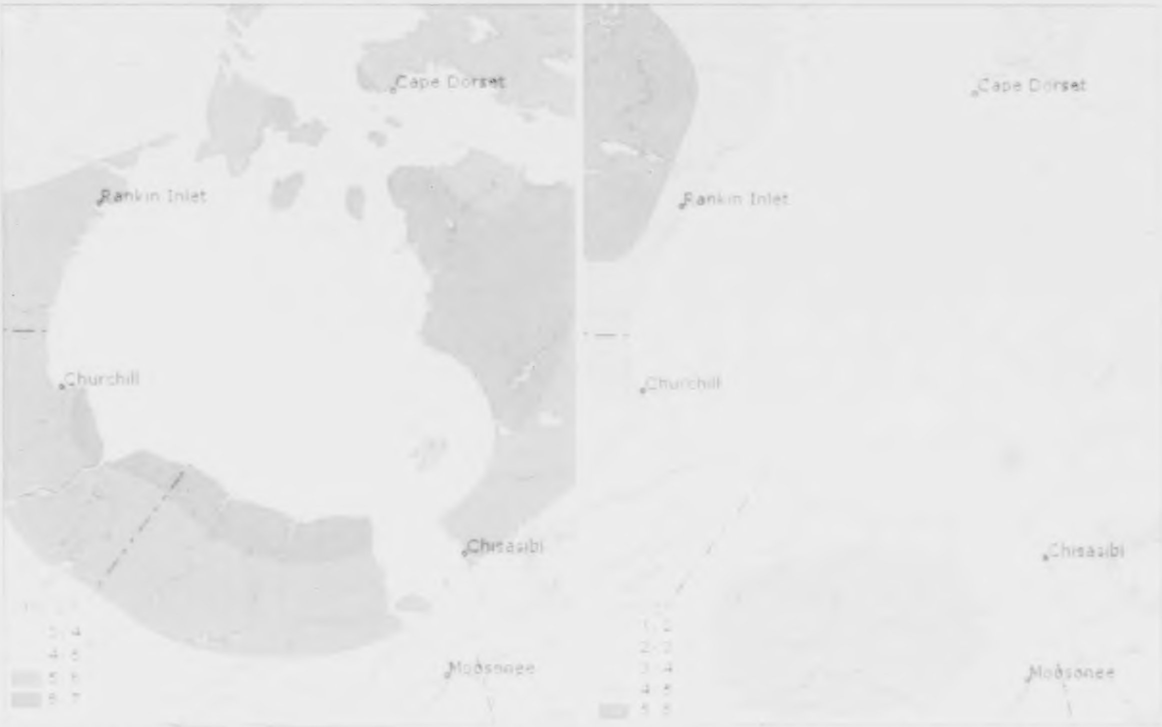


Figure 17-12. Change (°C) projected by the CCCma model in winter (December-February) and summer (June-August) air temperature from the reference period (1961-1990) to the middle of the current century (2040-2064) (from National Atlas of Canada 6th edn 2003c).

The Arctic Tundra biome may shrink until it is confined largely to the Arctic Islands. And, infilling by the taiga biome may not keep pace with the very rapid speed at which climatic warming is expected to occur. Within the existing treeline, the species composition of the forests is likely to change. Entire forest types may disappear, leading to new assemblages of species and ecosystems. The incidence of forest fires may increase and insect pests may move northward, reducing the yield of northern forests (Maxwell 1997). Timoney et al. (1992) provide a useful baseline for the location and composition of the treeline in Nunavut and the Northwest Territories against which change can be measured.

The subarctic peatlands south of Hudson Bay require a high, stable water table. They may be extremely vulnerable to climate change if warmer temperatures thaw the permafrost and affect their hydrology through changes in surface elevation, drainage, or flooding (Maxwell 1997).

Recent studies suggest that ice cover in Hudson Bay and James Bay will be reduced by climate warming but do not agree on the extent of the reduction. Global Climate Model results vary widely depending upon modelling parameters; some suggest that Hudson Bay may become ice free in winter (Cohen et al. 1994; Gough and Wolfe 2001). A three-dimensional coupled ice-ocean model also shows large reductions in the winter ice volume with climate warming (Saucier and Dionne 1998). It suggests that a simple 2°C increase in air temperature might reduce the sea ice produced in Hudson Bay by 20%, increase summer sea surface temperature by 4°C, and cause a two-week advance of breakup and delay of freezup. A comparison of sea ice concentration to melting degree day data suggests that warming of 1°C could advance ice break-up as much as two weeks in parts of the Bay (Etkin 1991). Because melting sea ice contributes more fresh water to Hudson Bay than does runoff, any change in ice cover will alter the freshwater budget (see Section 4.3), with wide ranging effects on the oceanography and ecology (see also Chapter 5 and Section 15.1).

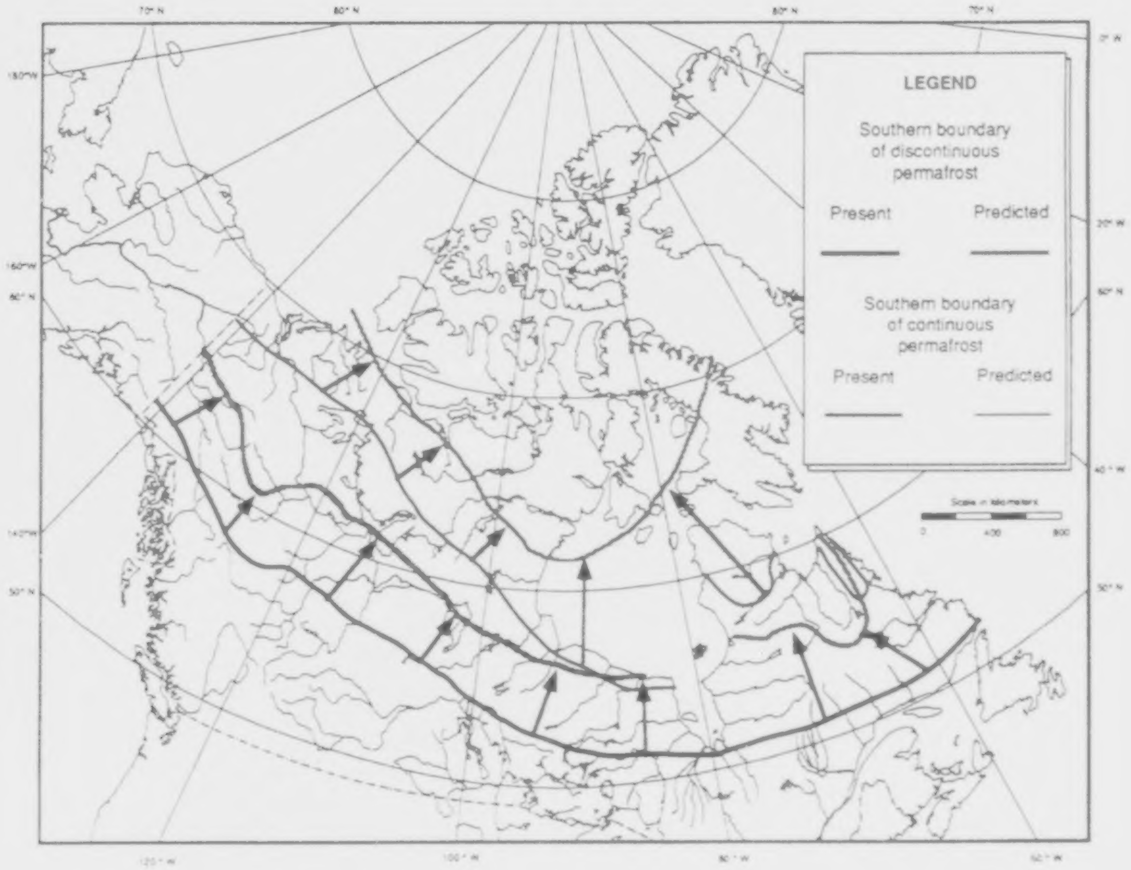

LEGEND
Southern boundary of discontinuous permafrost
Present
Predicted
Southern boundary of continuous permafrost
Present
Predicted
Scale in kilometers
0
400
800

Figure 17-13. Projected shift in the boundaries of discontinuous and continuous permafrost resulting from a surface temperature change of 4-5°C (from Woo et al. 1992:298). New boundaries are equilibrium positions assuming no change in other climatic factors or vegetation: it will take decades to centuries to reach equilibrium.

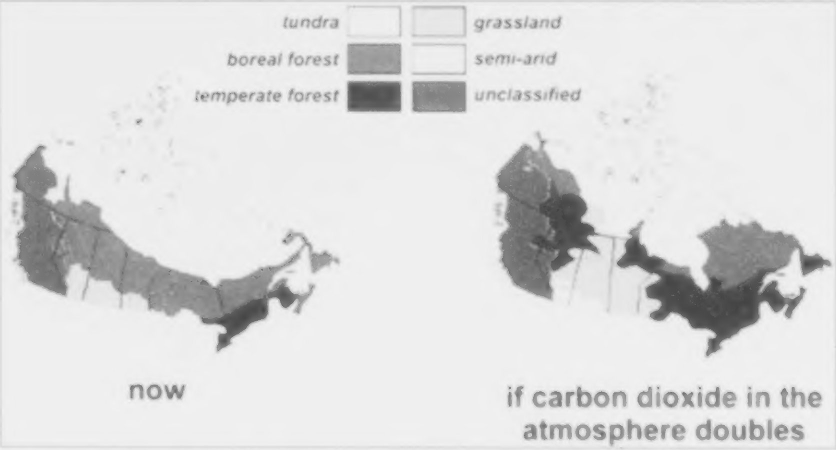


Figure 17-14. Predicted changes in vegetation if carbon dioxide in the atmosphere doubles (from Rizzo pers. comm. in Hengeveld 1995).

Glacial melting and thermal expansion of the world's oceans caused by climate warming may slow, halt, or even reverse the rate of coastal emergence in Hudson Bay and James Bay by offsetting the effects of isostatic rebound (Egginton and Andrews 1989; IPCC 1995 cited in Maxwell 1997; Gough 1998; Shaw et al. 1998). Three main factors cause the sea level to vary: changes in the earth's crust; changes in the amount of water stored on land as ice; and the thermal expansion or contraction of the World's oceans. Isostatic rebound is the main source of change in the earth's crust affecting the Hudson Bay marine ecosystem. It is causing the land to rise relative to the sea at a rate of 0.7 to 1.3 m per century (Andrews 1970 cited in Barr 1979; Hunter 1970; Webber et al. 1970; Hillaire-Marcel and Fairbridge 1978; Vincent 1989). Land-based glaciers and ice caps are a vast reservoir of water that, if melted, would enter the world's oceans. The net effect of climate warming on the largest of these, the Antarctic and Greenland ice sheets, is uncertain. Indeed, warming scenarios suggest that they may actually accumulate more water as a result of changes in precipitation than they might lose due to melting. Warming will also increase the volume of the world's oceans directly, since saline water expands when warmed. These increases in volume will cause the sea level around the world to rise. In the Hudson Bay marine ecosystem, results of 3-dimensional modelling analyses suggest that global sea-level rise will decrease the relative rate of local coastal rise due to isostatic rebound by at least 75% for a 3°C warming of the earth's surface (Gough 1998). The physical impact of this change would be least along low-lying coastal sections of James Bay and southern Hudson Bay, where the fastest isostatic rebound is occurring, but the biological impact in these areas could be severe if coastal salt marshes are adversely affected.

17.2.2 Precipitation and Hydrology

Precipitation scenarios from the CC92 GCM suggest a general increase in precipitation in the Hudson Bay region of between 0 and 30% for a doubling of atmospheric carbon dioxide, with the main increases in summer and autumn (Maxwell 1997). In winter and spring, northwestern Hudson Bay may receive less precipitation than at present (Figure 17-15). While this overall increase suggests that more water will be available for runoff, the water storage capacity of the land may increase substantially as permafrost melts--depending upon its ice content. More water may be stored underground and runoff may decrease (Soulis et al. 1994; Maxwell 1997). This could change the flow regime such that rainfall events rather than snowmelt dominate (Woo et al. 1992).

By 2050, ice may melt up to a month earlier in large rivers and up to 2 weeks earlier in large lakes (Maxwell 1997). The longer open water period and warmer conditions will increase evaporative loss from lakes, ponds and wetlands (Woo 1990; Boudreau and Rouse 1995; Schindler 2001) and affect their chemical, mineral, and nutrient status (Rouse et al. 1997). Changes in the precipitation regime may have a greater impact on the evapotranspiration of subarctic wetlands than the increase in air temperature (Eaton and Rouse 2001). Changes in vegetation cover will also modify evaporative losses over land. Coupled with permafrost degradation, these evaporative changes may alter the water balance such that some wetlands and shallow lakes disappear. The magnitude of the change in water balance will differ among terrains depending upon their evapotranspiration, runoff, and water storage characteristics (Boudreau and Rouse 1995; Eaton et al. 2001). Lakes with the smallest ratios of lake volume to catchment area are likely to be most affected (Rouse et al. 1997).

The effects of climate change on stream flow into Hudson Bay are not easy to predict because the pattern of change in temperature and precipitation will not be consistent across the region in time or space (Gagnon and Gough 2002). But, climate change will alter the volume of water available, the relative contributions of snowmelt and rainfall, and spatial and temporal flow patterns (Woo and McCann 1994; Schindler 2001). It may also alter the relationships between sediment and streamflow, and the runoff chemistry.

17.2.3 Wind

Reductions in the extent and/or duration of seasonal ice cover of Hudson Bay and James Bay will prolong the exposure of their surface waters to wind forcing. This may alter the wave climate and could increase the frequency of storm surges.

Figure 17-15. Change (%) projected by the CCCma model in winter (December-February) and summer (June-August) precipitation from the reference period (1961-1990) to the middle of the current century (2040-2064) (from National Atlas of Canada 6th edn 2003c).

17.3 POTENTIAL IMPACTS OF CLIMATE CHANGE

Residents of the Hudson Bay region are accustomed to dealing with seasonal and geographical variations in climate, so too are the vegetation and wildlife upon which they depend (Maxwell 1997; Hansell et al. 1998). The effects of these variations are reflected in all aspects of life and the environment. Plant communities are adapted to the local water, soil, and weather conditions; marine communities to seasonal ice cover; harvesters and tourists to the presence of plants and animals at a particular time and place; communities are designed to be compatible with permafrost; and ships are built to withstand expected wave heights and sea ice conditions. These and many more adaptations are ongoing in response to climate change. Two vital questions remain. Are plants and animals in the Hudson Bay marine ecosystem capable of adapting to the speed and magnitude of climate change that has been predicted? And, how might society best adapt? The following sections outline what may be some key impacts of climate change on the Hudson Bay marine ecosystem, to assist with future planning initiatives.

The strong climatic linkages between Hudson Bay and its surroundings mean that coastal environments may be doubly impacted by climate change (Rouse 1991). They will be warmed more by overall global temperature warming and cooled less during the growing season by air originating over Hudson Bay. This will increase evapotranspiration from the wetlands; causing them to dry and reducing water yield for stream flow. It will cause permfrost degradation and favour northward movement of vegetation zones. Warmer drier soil conditions may cause the peat soils of wetland tundra to release rather than accumulate carbon dioxide from the atmosphere (Burton *et* al. 1996). The natural incidence of forest fires may increase. Climate change may simply cause a spatial shift of an ecozone or climate region (i.e., northward), or it may create a new type not previously observed (Whitfield et al. 2002).

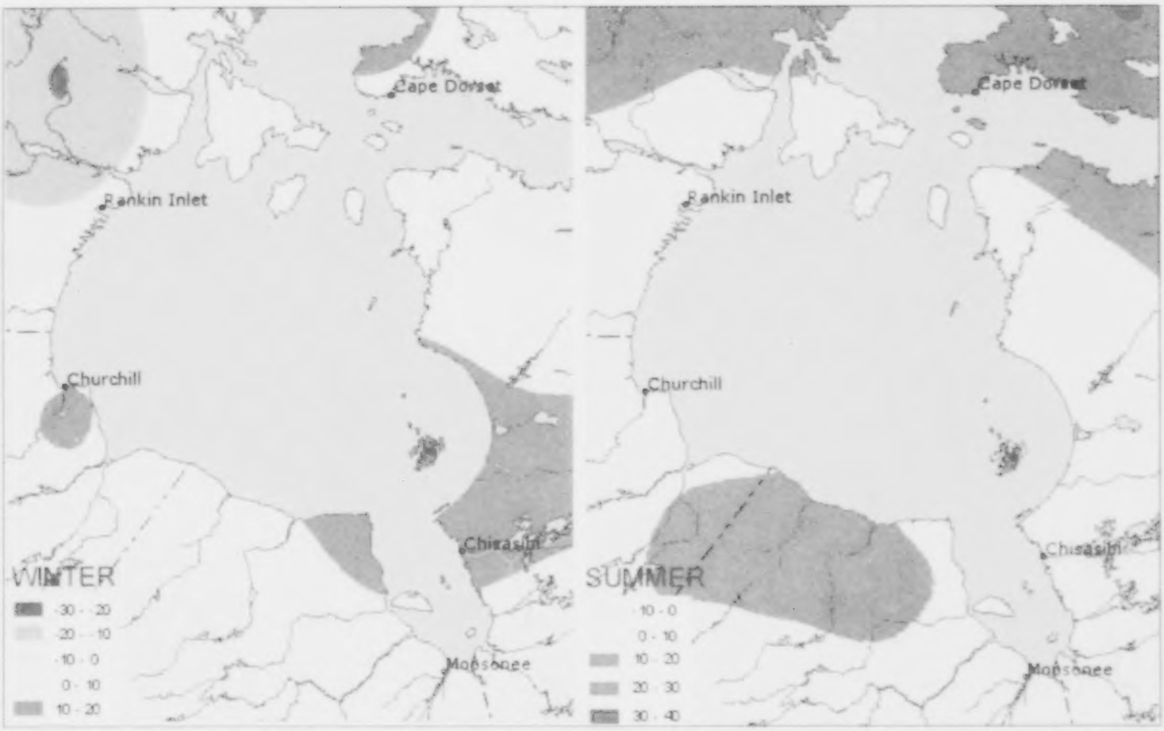


Figure 17-15. **Change (%) projected by the CCCma model in winter (December-February) and summer (June-August) precipitation from the reference period (1961-1990) to the middle of the current century (2040-2064) (from National Atlas of Canada 6th edn 2003c).**

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17.3.1 Oceanography

While the satellite sea ice data show changes in the sea ice, they do not explain their causes or predict future changes (Parkinson and Cavalieri 2002). If the observed changes are tied most closely to Arctic warming (Martin et al. 1997; Serreze et al. 2000) that continues, then the ice cover should continue to decrease; but, if the sea-ice changes are tied more closely to oscillatory changes in the climate system, such as the North Atlantic Oscillation and the Arctic Oscillation (Deser et al. 2000; Morison et al. 2000; Parkinson 2000), then sea ice cover will likely fluctuate (Parkinson and Cavalieri 2002). This uncertainty means that extrapolations of decreases seen in the sea ice cover in the 1990's should be done with caution (Parkinson 2000a).

Changes in the ice cover have major implications for the Hudson Bay marine ecosystem. The reduction or loss of seasonal ice cover would reduce or eliminate the most important component of the freshwater budget of the bay (i.e., sea ice melt) and threaten existing ecosystems (Cohen et al. 1994; Ingram et al. 1996; Ingram and Prinsenberg 1998; Carmack and Macdonald 2002; Macdonald et al. 2003b). How changes in the ice environment affect each species will depend very much on the exact way in which the animal or plant uses ice, and on the plasticity of that use.

A reduction or elimination of seasonal ice cover would:

- initially increase and eventually reduce or eliminate polynya and ice edge habitats that are important areas for the exchange of energy between ecosystems;
- alter seasonal tidal spectrums by reducing or eliminating the damping effects of ice cover;
- reduce or eliminate coastal ice scour and the redistribution of sediment and other material trapped within the ice or carried on its upper or lower surface;
- increase surface salinity by reducing or eliminating the release of fresh water at the surface by melting sea ice. With a thinner layer of low salinity water at the surface, and longer open water period, wind mixing should make more nutrients available to primary producers in the upper water column (Dunbar 1993).
- make more light available to primary producers;
- increase surface water temperature and reduce or eliminate freezing of macrophytes;
- reduce or eliminate ice habitats, their associated biota and seasonal biological production; and
- trigger trophic changes, from the bottom up and top down (Macdonald et al. 2003b).

A shorter duration of ice cover when coupled with stronger winds may:

- increase re-working of coastal habitats by wave action, leading to increases in longshore sediment transport and changes in spit and delta formation [Note: because much of the coastline is low-lying or rocky, these changes are unlikely to be severe as in areas with steep, unconsolidated shorelines such as the Beaufort Sea.];
- increase winter mixing and upwelling, and thereby the nutrients available to phytoplankton (Carmack and Macdonald 2002);
- favour more severe wave development and more frequent storm surges; and

- lead to warmer temperatures and earlier melt in coastal areas. The rate of evapotranspiration would increase and could lead to drying of wetlands and lengthening of the growing season.

These changes are not necessarily linear and there may be a few threshold responses and non-linear surprises. There may also be unexpected cumulative effects when impacts of climate change interact with those from other environmental stressors, such as hydroelectric development (see also Section 15.1).

17.3.2 Plants

If ice does not form, primary production by ice algae would be eliminated. However, the effects of decreasing ice cover are less certain, as changes in light and nutrient availability related to the depth of snow cover, ice thickness, extent of ice cover, and timing of breakup relative to the incoming solar radiation are complex. In either case, elimination or reduction, the timing, location, and magnitude of primary production are likely to change and to affect animal populations and their ability to adapt to other environmental change. Reduction or elimination of seasonal ice formation would permit the establishment of richer benthic macrophyte communities. Plants would no longer be subject to freezing, ice scour, or seasonal light deprivation to the same extent. These changes to planktonic and benthic plant communities may alter the quantity, quality, and distribution of food available to consumers and thereby trophic dynamics (Macdonald et al. 2003b).

Glacial meltwaters that offset isostatic rebound along low-lying coastal sections will effectively reduce the rate of coastal emergence, at least over the short term (several hundred years?). Tidal salt marshes are diverse and highly productive ecosystems that exist within a small elevation range relative to sea level and rely on a variety of processes for their continued existence. Altering the rate of coastal emergence may reduce the extent of these marshes, as inland vegetation will tend to encroach on the marsh and new marsh will not be created at the same rate on the seaward side. These effects might be partially offset by the reduction or elimination of erosion by shore ice and of freeze-thaw processes in intertidal sediments. This may alter the amount and composition of plant resources available to birds.

Reducing the ice cover and thickness should also reduce seasonal ice damage to eelgrass beds. Whether this will facilitate expansion of the beds and increase their biological productivity is unknown, as ice can also promote eelgrass growth by removing dead plant material. Perhaps, in the absence of ice, increased wave action may perform the same task.

17.3.3 Invertebrates

If ice no longer forms, secondary production by ice fauna will be eliminated. However, as with ice flora, the effects of more subtle changes in the ice cover on invertebrate ice fauna and production are hard to predict. Overall, warmer water and reduced ice cover should increase nutrient recycling and biological productivity (Dunbar 1993). The reduction or elimination of seasonal ice formation would enable the establishment of richer communities of molluscs and other invertebrates in the nearshore zone that is now subject to freezing and ice scour. Southern species may invade; some northern species may grow faster and larger. Changes in plant communities may alter the flow of food energy among epontic, pelagic, and benthic habitats and thereby alter invertebrate trophic dynamics (Macdonald et al. 2003b). Opportunities for the commercial harvest of marine invertebrates may improve over time.

Parasitic invertebrates may also be influenced by climate change (Marcogliese 2001). Depending upon how changes affect their hosts, some species may be extirpated locally and others introduced. Parasite transmission and possibly virulence may also be affected.

17.3.4 Fish

Fish in Hudson Bay and James Bay will be affected by changes in water temperature, ice cover, salinity, and nutrients. These changes will affect the quality and availability of ice edge and nearshore habitats, and of plant and invertebrate food resources. They will cause shifts in species distributions and in the biological productivity of fish species and communities (Shuter et al. 1998; Macdonald et al. 2003b). Indirect evidence from changes in the diet of seabirds suggests that climatic warming may cause Arctic cod and some benthic sculpins and zoarcids to become less abundant, while capelin and sand lance become more abundant (Gaston et al. 2003).

The IPCC (1995) has estimated that many species in lakes and streams are likely to shift northward by about 150 km for each 1°C increase in air temperature. This axiom may also be useful for estimating oceanic impacts, at a general level (Maxwell 1997). The northward expansion of freshwater fishes such as brook trout and northern pike may, for example, reduce or eliminate Arctic charr populations along the Hudson Bay coasts since the distributions of these species seldom overlap. The presence of Arctic waters in Foxe Basin and Hudson Strait may slow or prevent the invasion of some subarctic marine species.

Changes in the seasonality of streamflow may affect access of anadromous species moving between freshwater and marine environments in the spring and fall. It may also affect their access to headwater lakes for spawning. The productivity of other species that traditionally have been harvested from these lakes may also change, but the effects on overall fish productivity are uncertain (see Minns and Moore 1992; Reist 1994; Rouse et al. 1997; Shuter et al. 1998; Schindler 2001). Freshet timing and plume dynamics are also important determinants of the feeding success of marine fish larvae (e.g., Arctic cod and sand lance) (Fortier et al. 1996). The impact hydrological changes related to climate fluctuations, and/or hydroelectric developments, have on recruitment will likely depend upon what fraction of the larval dispersal area is affected by river plumes.

17.3.5 Marine Mammals

Climatic warming may favour some migratory marine mammals such as belugas, bowheads, harp seals, and hooded seals by improving seasonal access. The effects of changes in the availability of suitable prey species are less certain, with the exception of important ice-associated prey such as Arctic cod and sympagic (with ice) amphipods which are likely to become less abundant (Tynan and DeMaster 1997). The fact that belugas frequent warmer estuaries in southern Canada suggests that warming will not force them to vacate important estuarine habitats in Hudson Bay where they summer. However, the attractiveness of some estuaries may change if there are large changes in flow. Both the whales and seals may be subject to increased predation from killer whales and to competition from other whale and dolphin species that may invade from southern latitudes. Changes in sea ice concentrations in areas of the North Atlantic where harp and hooded seals breed may affect their populations and limit their need or ability to take greater advantage of a warmer Hudson Bay marine ecosystem.

Non-migratory harbour seals might also benefit from climatic warming, as they would be less vulnerable to harvest and predation in the winter when ice limits their movements in coastal estuaries and rivers. If more areas along the coast of Hudson Bay and James Bay, and in the lower reaches of their tributaries, remain open year-round the harbour seal population may disperse and increase. However, subsistence hunting pressure on harbour seals may increase if fewer ringed and bearded seals are available.

Partial or total loss of the seasonal snow or ice cover may be disasterous for resident, ice-adapted species such as ringed and bearded seals, and the polar bear (Stirling and Derocher 1993; Stirling and Lunn 1996; Stirling et al. 1999; Stirling and Smith 2004). Each of these species has particular requirements for the duration and quality of ice cover and for its distribution relative to feeding resources. Ringed seals build birthing lairs on the ice to provide shelter from the time they give birth until the pups are ready to enter the water. If the snow cover deteriorates too early in the season the lairs collapse, killing or exposing the pups; if the ice melts before they are ready to enter the water the pups die. Seals also haul out on the ice to keep dry and warm during moult. The question of how they may respond if the period of ice cover shortens and/or the quality of that cover deteriorates for breeding purposes is vitally important to seals, Inuit, and polar bears. An Inuit elder has suggested that ringed seals may move ashore to pup if ice is not available during the pupping season, and thereby become more vulnerable to predation by polar bears (Cleator 2001:18). Alternatively, the seals may adjust their pupping dates to correspond to changing ice conditions and snow cover, or simply disappear from the region. The ability of seals to adapt to changes in the fish and invertebrate communities, particularly to any decline in the availability of key prey species (e.g., Arctic cod for ringed seal), is unknown. Any decline in the polar bear populations should have a positive effect on seal survival.

Changes in the sea ice that decrease the availability of seals will have an important negative effect on polar bear populations. These changes may already be happening in western Hudson Bay (Stirling and Derocher 1993; Stirling et al. 1999). Breeding populations will be eliminated from western Hudson Bay if females are unable to build up enough fat reserves over the winter to sustain themselves and their offspring over the following summer. This is likely to occur well before seal populations are seriously affected by climate change and well before the seasonal ice cover is lost. In the short term, affected bears may move north or east to areas less affected by warming, and they may become more aggressive in their search for food around humans. Inuit in eastern Hudson Bay have observed both of these changes but cannot attribute them directly to climate change (McDonald et al. 1997). In the long term, depending upon the extent of ice loss, bear populations may disappear from part or all of Hudson Bay and James Bay. Permafrost melting and heavier spring rains may cause more earth dens to collapse, and thereby increase mortality and decrease reproductive success. Overheating could become a problem for bears summering along the coasts.

The effects of ice habitat loss on narwhals are uncertain (Stewart 2004a). While they frequent northern Hudson Bay in summer, when the ice cover is least, they have a great affinity for areas with seasonal ice cover. Whether they would continue to visit the Respulse Bay area in the absence of seasonal ice cover is unknown. Reduced ice coverage may make narwhals more susceptible to predation by killer whales.

The direct effects of climatic warming or cooling on walruses likely are limited, and not necessarily negative. Born et al. (2003) hypothesized that a decrease in the extent and duration of Arctic sea ice in response to warming might increase food availability for walruses by increasing bivalve production, and improve seasonal access to rich feeding habitat in shallow inshore waters. However, the positive effects of these changes are by no means certain, as there may be unforeseen energetic costs associated with foraging or other activities. Behavioural and physiological responses to changes in air temperature suggest that Pacific walrus calves can maintain their body temperature at an air temperature of 18°C in still air and shade or under equivalent conditions (Fay and Ray 1968; Ray and Fay 1968). Above this temperature they withdraw into the water to avoid over heating. Air temperatures at or above this level for an extended period might disrupt normal feeding, moulting, and calving schedules. Walrus breed on the ice and the males appear to require ice habitat in order to establish territories and control harems (R. Stewart, DFO, Winnipeg pers. comm. 2003). In the event of climate warming, a northward expansion of human populations could reduce the availability of suitable walrus habitat and increase harvesting pressures (Stewart 2004b).

17.3.6 Birds

Climate change may alter the routes and destinations of migratory birds. Their ability to adapt to potentially rapid changes in key staging areas may be of critical importance to their futures. Transient species passing through the Hudson Bay marine ecosystem require appropriate time and space linkages for successful passage (Morrison and Gaston 1986). Given the dependance of so many species on the timing of break-up and freeze-up, changes to either could have extremely wide-reaching effects. Likewise, any reduction in the size or quality of salt marsh habitats that breeding waterfowl depend upon for food would adversely affect breeding success. Changes in coastal vegetation and wildlife could also reduce breeding success and cause species that breed on the tundra to relocate northward.

Birds using the Hudson Bay marine ecosystem on a seasonal basis may also be impacted by the effects of climate change in areas outside the region, where they lay down the fat stores necessary for successful Arctic breeding (Diamond 1998). These changes could have a detrimental effect on the populations regardless of changes in the Arctic. Cliff-nesting seabirds would have earlier and longer access to marine resources.

Changes in the relative abundance of prey species may cause some species, such as the thick-billed murre, to alter their diets and may attract other species, such as razorbill, to colonize the area (Gaston et al. 2003). Changes in coastal habitats could attract southern bird species, and terrestrial invertebrate and mammal species, to invade. Their presence as competitors/parasites/predators could make coastal habitats less attractive to bird species that currently breed, feed, and moult along the region's coasts.

17.3.7 Biodiversity

Climate warming will selectively eliminate from the Hudson Bay marine ecosystem Arctic biota that cannot adapt or relocate to suitable habitats quickly enough to survive. Ice-adapted species will be the most affected; species that occur over a wide range of latitudes will be least affected (Ingram et al. 1996). Warming may increase the opportunity for north temperate species to invade Hudson Bay (Hansell et al. 1998). However, most will have to do so via Hudson Strait, which may remain unfavourably cold. Relict species that live in James Bay may invade Hudson Bay but most southern species must enter via Hudson Strait. The lag between Arctic species receding and temperate species invading will likely reduce the biodiversity of southern Hudson Bay for some time. Interspecific interactions between predators and prey, and among warm and cold adapted species of competitors, will likely change if warming modifies communities—marine, freshwater, or terrestrial.

17.3.8 Human Activities

Climate change may fundamentally alter the local environment and resource base of communities, such that traditional knowledge is no longer applicable (Maxwell 1997; McDonald et al. 1997; Thorpe et al. 2002; Duerden 2004). This will make the outcomes of important decisions related to the environment--especially to harvesting and travel, less certain and effect major changes in the life style, housing, harvesting, and health of people who live along the coasts of Hudson Bay and James Bay and use the resources of the marine ecosystem (Fast and Berkes 1998; Maxwell 1997; Hansell et al. 1998; Ford and Smit 2004). Communities that retain the strongest links to the land and enterprises that depend on local conditions will be most directly affected, and these effects may be most pronounced along the southern and western coasts. Key species for which harvesting rights have been guaranteed to Inuit and Cree under comprehensive land claims agreements may no longer sustain current harvest levels (Fenge 2001). This may force the people with the lowest cash income to pay more for food and result in dietary and epidemiological changes that affect the health of area residents (Fast and Berkes 1998; Furgal et al. 2002; Duerden 2004). Climate change is just one of the stressors acting on northern Inuit and Cree communities, the cumulative effects of which may be greater than the sum of their parts.

Harvesting

While the end result of warming that is significant enough to reduce the ice volume in Hudson Bay and James Bay is likely an increase in biological productivity (Dunbar 1993), the direction and degree of change at any time during the transition is impossible to predict given the complexity of the changes that may occur. Ultimately the fisheries harvest potential may increase but the transition is unlikely to be smooth, as the biological communities and their production will be in flux. Climate change may alter both the target species and their catchability in time and space. Belugas, brook trout, and blue mussels are species that may benefit from warming—the extent will depend upon a myriad of factors, while populations of other key species, such as Arctic charr, ringed and bearded seals, and narwhals, may be reduced or disappear from the region altogether.

Traditional harvesters could face a very difficult transition as they adjust to changes in the physical environment and in species composition and availability. Initially, the migratory patterns of biota (e.g., anadromous Arctic charr) that have been available to generations of harvesters at a predictable time and location might change; eventually these species might be replaced by unfamiliar invaders (e.g., brook trout). Wholesale shifts in the focus of harvesting efforts may result--geographically, seasonally, and in terms of the target species (marine, freshwater, and terrestrial). The food value and economic value of commercial harvests may also fluctuate widely with changes in species availability and product demand until some future steady state is reached. Over the long term, a northward expansion of agriculture and forestry may occur, providing a more diverse renewable resource base for development.

Transportation

Northward expansion of agriculture, forestry, and mining activities may require the expansion of transportation networks. How this might affect development along the Hudson Bay and James Bay coasts is unknown. Permafrost melting likely will increase maintenance costs for existing runways and road and rail beds, at least in the short term (Maxwell 1997).

The impact of climate change on coastal travel between communities is uncertain. The reduction or elimination of landfast ice will reduce or eliminate coastal travel by snowmobile, Bombardier, and dog-team. This may be offset by a longer open water period that facilitates small craft travel between communities. Whether the overall effect is positive or negative will depend upon changes in the wave climate, susceptibility to superstructure icing, and many other factors. Warmer temperatures will shorten the period when winter roads can be used and may eliminate them in some areas.

The longer ice-free season would benefit floatplanes but this would be offset by reductions in ski-plane access. It may significantly lengthen the period wherein ships without hulls strengthened to withstand ice can visit ports and communities in the region (Maxwell 1997). This could increase ship traffic to and from the Port of Churchill in particular, and might alter the seasonal nature of community re-supply by ships from eastern Canada and shipping disturbances to marine mammals. Increased sediment transport may require more frequent surveys to monitor local shoaling and necessitate more frequent harbour dredging. Warmer, less dense air would reduce the lift available to aircraft and thereby their load-carrying capacity.

Increases in precipitation and in storm frequencies might increase the need for navigational aids and for search and rescue capabilities in the region (Maxwell 1997). It may also increase down time for air and watercraft. The effects of hydrological changes on boat traffic are uncertain but will likely vary among localities.

Oil and gas development

While climate change should ease the environmental conditions under which offshore oil and gas exploration and development are carried out; this may not be reflected in the cost of operations (Maxwell 1997). A longer open-water season would facilitate ship-borne drilling and testing operations for offshore oil and gas wells, enabling them to be completed in one season. These cost savings might be offset somewhat by stronger wave action. While decreases in the duration and thickness of ice cover would reduce the cost of production by reducing construction costs, the loss of seasonal ice cover would enable a switch to conventional offshore technology that could result in important cost savings. It would also reduce or eliminate the need to protect pipelines from ice scour by trenching and/or enable the use of tankers. Changes in the permafrost and in coastal conditions could have significant design and cost implications for onshore pipeline developments. Uncertainties in climate scenarios and the conservative nature of the industry are such that climate change may not cause an increase in operations in the Canadian Arctic, since the positive impacts of climate change cannot be incorporated into current designs and the negative impacts must be considered.

Building and construction

Increased air temperatures will reduce heating and insulation costs and lengthen the summer building season (Maxwell 1997). It may negatively effect heavy construction that takes advantage of ice or permafrost to support equipment or provide stability. In general, the main building and construction concerns are related to changes in permafrost. They include questions related to the stability of pipelines, pile foundations, and open pit mine walls, and on the release of contaminants sequestered in frozen tailings. The effects of changes in runoff, related to changes in precipitation and soil permeability, on bridges, pipeline river crossings, dykes and erosion protection structures, are difficult to assess.

Recreation and tourism

The effects of climate change on wind and visibility are not well known. These factors are important to tourism and lack of this knowledge hampers effects assessments (Maxwell 1997). Climate change would remove some or many of the Arctic features of the Hudson Bay environment--marine, freshwater, and terrestrial. This would fundamentally alter its attraction for tourists as a relatively accessible and cost effective location for viewing Arctic biota and experiencing the Arctic environment and seasons. Polar bears for example may no longer frequent Polar Bear Provincial Park in Ontario or Wapusk National Park in northern Manitoba. Depending upon the extent of the climate change, some aspects may remain, such as viewing opportunities for migratory birds and beluga whales. These negative effects might be offset somewhat by lengthening of the summer tourist season and improved access from the south. The impact of climate change on river recreation, particularly canoeing and kayaking, should be small and could be positive.

17.3.9 Contaminants

Climate change and variability could alter risk from contaminants in the Hudson Bay marine ecosystem by changing their transport to and from the ecosystem and bioaccumulation within the ecosystem (Macdonald et al. 2002, 2003c; see also Schindler 2001). The direction and extent of these changes are unpredictable, given the complexity of climate-driven changes to the marine ecosystem and its surroundings, and will likely vary over time and space. In the instance of mercury, for example, warming of permafrost-dominated terrains west of Hudson Bay may increase the erosion of particles, and the methylation and hence biological accumulation of mercury. Changes in temperature and hydrology can also alter the nature of scavenging of organic contaminants by rain and snow, and individual lipid dynamics which, coupled with changes in trophic structure (population size distribution, length of food chain), could alter the availability of contaminants to humans (Macdonald et al. 2002).

17.4 SUMMARY

The effects of climate change on the Hudson Bay marine ecosystem are difficult to predict and assess, but could be far-reaching. Changes have been observed in air temperature and precipitation, and are manifest in stream flow into Hudson Bay, sea ice, and biota. There is evidence of warming in western Hudson Bay and cooling in the east, and of increasing annual precipitation with trends toward greater precipitation in spring, summer, and autumn. River discharges are peaking earlier in the spring from Manitoba to Quebec, while total discharge has decreased in central Manitoba and increased in the Kazan River. Perhaps the most telling evidence of climate change is in the ice cover record derived from Satellite passive-microwave data. From 1979-96, the length of the sea ice season decreased in northwest Hudson Bay and along the southern coasts of Hudson Bay and James Bay, but increased in east central Hudson Bay and near the Belcher Islands and Akimiski Island. If these changes are tied most closely to Arctic warming that continues, then the ice cover should continue to decrease; but, if the sea-ice changes are tied more closely to oscillatory changes in the climate system, such as the North Atlantic Oscillation and the Arctic Oscillation, then sea ice cover will likely fluctuate. This uncertainty means that extrapolations of decreases seen in the sea ice cover in the 1990's should be done with caution.

Climate change may also be affecting the polar bears in western Hudson Bay. Their dependence on ice cover makes them very vulnerable to changes in its quality, distribution, and duration. Recent declines in body condition, reproductive rates and cub survival, and an increase in polar bear-human interactions, suggest that these bears are under increasing nutritional stress. These changes have been correlated with earlier breakup and later freeze-up that have increased the ice-free period, reducing feeding opportunities and prolonging their fast.

While many scientists agree that there is a high probability of global warming during the next century, they are less certain about its causative factors, rate, extent, and regional effects. The role played by the world's oceans in climate change is also poorly understood. Elaborate computer models have been developed to improve understanding of how the climate may respond to increases in greenhouse gas concentrations. These "general circulation models or GCMs" often simulate the type of climate that might exist if global concentrations of carbon dioxide were twice their pre-industrial levels. They use mathematical equations to represent physical processes of the climate system—particularly those involving radiation, heat and motion and the water cycle; and to calculate the interactions between these processes. Strictly speaking, they are not predictive models but rather a means of determining the sensitivity of the climate system to a change in one of its key elements.

Climate change scenarios derived from these models must be used with caution, as they are very sensitive to the choice of modeling parameters and different models can yield very different results. A model that more accurately represents the regional oceanography year round is being developed and will be embedded into a larger climate model to improve its predictive ability for Hudson Bay. Improvements are also needed to the atmospheric model, particularly with respect to low-level atmospheric fields (e.g., lower winds and higher temperature) and the effects of aerosols. As changes in temperature (first order) alter ice formation (second order), which affects sediment transport, primary production, foodweb dynamics, etc., (third order), a few threshold responses and non-linear surprises likely will be encountered (R. Macdonald, DFO, Sidney, BC pers. comm. 2004). Some of these thresholds, such as 0°C, will be more important than others when it comes to biological distributions. Consequently, better understanding of the regional oceanography and of threshold effects that might cause abrupt changes is needed to underpin these models.

The GCM developed by the Canadian Centre for Climate Modelling and Analysis (CCC92) predicts a winter warming of up to 10°C and summer warming of 1-2°C by 2100 in central Hudson Bay; smaller increases are predicted in winter (6-9°C) and greater increases in summer (2-5°C) along the coasts. Precipitation scenarios from this model suggest a general increase in precipitation in the Hudson Bay region of between 0 and 30% for a doubling of atmospheric carbon dioxide. Precipitation should increase throughout much of the region over most of the year, but mainly in summer and autumn. In winter and spring, northwestern Hudson Bay may receive less precipitation than at present. Glacial melting and thermal expansion of the world's oceans caused by climate warming may slow, halt, or even reverse the rate of coastal emergence in Hudson Bay and James Bay by offsetting the effects of isostatic rebound. Results of 3-dimensional modelling analyses suggest that this rise will decrease the rate of coastal emergence by at least 75% for a 3°C warming of the earth's surface. The physical impact of this change would be least along low-lying coastal sections of James Bay and southern Hudson Bay, where the fastest isostatic rebound is occurring.

The strong climatic linkages between Hudson Bay and its surroundings mean that coastal environments may be doubly impacted by climate change. They will be warmed more by overall global temperature warming and cooled less during the growing season by air originating over Hudson Bay. This will increase evapotranspiration from the wetlands; causing them to dry and reducing water yield for stream flow. It will cause permfrost degradation and favour northward movement of vegetation zones. The Arctic Tundra biome may shrink until it is confined largely to the Arctic Islands. Infilling by the taiga biome may not keep pace with the very rapid speed at which climatic warming is expected to occur. Within the existing treeline, the species composition of the forests is likely to change. More water may be stored underground and runoff may decrease. This could change the flow regime such that rainfall events rather than snowmelt dominate runoff. Warmer drier soil conditions may cause the peat soils of wetland tundra to release rather than accumulate carbon dioxide from the atmosphere. The natural incidence of forest fires may increase. Climate change may simply cause a spatial shift of an ecozone or climate region, or it may create a new type not previously observed.

Recent studies suggest that ice cover in Hudson Bay and James Bay will be reduced by climate warming but do not agree on the extent of the reduction. Some GCMs suggest that Hudson Bay may become ice free in winter. A three-dimensional coupled ice-ocean model suggests that a simple 2°C increase in air temperature might reduce volume of the sea ice produced in Hudson Bay by 20%, increase summer sea surface temperature by 4°C, and cause a two-week advance of breakup and delay of freezup. Because melting sea ice contributes more fresh water to Hudson Bay than does runoff, any change in ice cover will alter the freshwater budget.

The reduction or loss of seasonal ice cover has major oceanographic and ecological implications. A progressive loss of ice cover initially would increase, and eventually reduce or eliminate polynya and ice edge habitats that are important areas for the exchange of energy. It would increase surface salinity by reducing or eliminating the dilution of surface waters by freshwater released from melting sea ice. With a thinner layer of low salinity water at the surface, and longer open water period, wind mixing should make more nutrients available to primary producers in the upper water column. More of the light incident at the surface would be available to primary producers. Damage to plants and bottom habitats caused by freezing and ice scour would decrease, and ice habitats and their associated biota would be reduced or eliminated. More severe wave development would be favoured and storm surges could also become more frequent.

Climate change has the potential to affect the spatial distribution of biota in and around the Hudson Bay marine ecosystem. Species that cannot adapt to changes in habitat or food resources will be selectively eliminated. The effects on each species may depend in large part on how they use and interact with the ice environment, and on how plastic that use is. Ice-adapted species such as ice algae, sympagic amphipods, polar bears, and ringed and bearded seals, would likely be most affected by climatic warming. Breeding populations of polar bears could disappear from the region well before seals are affected seriously by changing ice cover. The effects of ice habitat loss on narwhals are uncertain, given their great affinity for areas with seasonal ice cover, while the direct effects on walruses may be limited and not necessarily negative. Warming may favour species such as belugas, bowheads, and harbour, harp and hooded seals by improving seasonal assess, but it could also alter their food resources and lead to increased predation by killer whales. Subarctic species may invade, although most aquatic species will have to do so via Hudson Strait, which may remain unfavourably cold. The lag between Arctic species receding and these species invading could reduce the biodiversity of southern Hudson Bay for some time.

While warming is likely to increase biological productivity over the long term, the direction and degree of change at any time during the transition is impossible to predict. Shifts may occur within and among communities and species, and the overall marine production will rise and fall until stability is regained. There will be more light and nutrients available for marine plant growth, and the reduction or elimination of ice scour and surface freezing will enable more plants and invertebrates to colonize the nearshore zone. Offsetting these changes will be the loss of production by ice algae and ice-adapted biota. Each consumer's share of the available production will depend on how well it adapts or is adapted to the environmental conditions. This will affect the sustainable harvest that individual species and particular locations can support. Scallops and mussels, for example, may grow faster and larger. Arctic charr may become more productive over the short term, in response to increased nearshore production, but over the long term may be replaced by other species, such as brook trout, that move northward to take advantage of increasingly favourable habitats.

Migratory birds visiting the Hudson Bay marine ecosystem rely on appropriate time and space linkages for successful passage. Given the dependance of so many species on the timing of break-up and freeze-up, changes to either could have extremely wide-reaching effects. Likewise, any reduction in the size or quality of salt marsh habitats that breeding waterfowl depend upon for food would adversely affect breeding success. Altering the rate of coastal emergence may reduce the extent of coastal salt marshes, as inland vegetation will tend to encroach on the marsh and new marsh will not be created at the same rate on the seaward side. Changes in coastal vegetation and wildlife could also reduce breeding success and cause species that breed and moult on the tundra to relocate northward. Cliff-nesting seabirds would have earlier and longer access to marine resources. Changes in the relative abundance of prey species may cause some species, such as the thick-billed murre, to alter their diets and may attract other species, such as razorbill, to colonize the area. Birds using the Hudson Bay marine ecosystem on a seasonal basis may also be impacted by the effects of climate change in areas outside the region, where they lay down the fat stores necessary for successful breeding.

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Appendices

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APPENDIX 1 BENTHIC, MULTICELLULAR ALGAE REPORTED FROM HUDSON BAY AND JAMES BAY

Footnotes and symbol explanations are located at the end of Appendix 1 on page A-6.

SPECIES	JAMES BAY MARINE REGION		HUDSON BAY MARINE REGION	COMMENTS ON OCCURRENCE
	James Bay	southeastern Hudson Bay		
Cl. Chlorophyceae (green algae) - multicellular, attached and macroscopic				
Chlorochytrium dermatocolax Reinke	L			
Chlorochytrium moorei Gard		BC		
Chaetomorpha melagonium (Web. and Mohr) Kutz		BC		intertidal to 25 m depth, attached to rocks or loose-lying.
Cladophora sp.	BC,La	BC		at depths of 2-15 m on rocks or loose-lying, sometimes with eelgrass.
Cladophora kuetzingiana Grunow in Rabenhorst		BC	Wc	brackish lagoon.
Enteromorpha ahlnerana Blid.	*			
Enteromorpha clathrata (Roth) Grev.		BC		
Enteromorpha compressa (L.) Grev.		S	BM	enclosed bays or tidal estuaries.
Enteromorpha crinita (Roth) J. Ag.	SC			
Enteromorpha flexuosa parasoxa (Dillw.) Blid.	H,L			intertidal at Ekwan R.,subtidal at the 5-6 m depth at Charlton I.
Enteromorpha groenlandica (J. Ag.) Setch.& Gard.		BC		
Enteromorpha intestinalis (L.) Link.	SC,BM,BC,L	BC	BM,Wc	on intertidal boulders at Ekwan R.; enclosed bays or tidal estuaries.
Enteromorpha prolifera (O.F. Mull.) J. Ag.	H,BM,BC,L	BC		on intertidal boulders and free-floating at Ekwan R.
Percursaria percursa (C. Ag.) Rosenv.		BC		intertidal on rocks.
Rhizoclonium riparium (Roth.) Harv.	*,D,La			intertidal on cobbles pebbles often with eelgrass.
Spongomorpha arcta (Dillw.) Kütz.	BC			
Ulothrix sp.	BC	BC		
Ulva flacca (Dillw.) Thuret in Le Jolis			Wc	rocky tidal pools.
Ulva lactuca L.	SC,BC			
Cl. Phaeophyceae (brown algae) - largest algae, multicellular, superficially resemble higher plants.				
Agarum cribrosum (Mert.) Bory	SC			on rocks at 5-35 m depth [O].
Agarum turneri Post. And Rupr.			BM,SC	deep water.
Alaria esculenta (L.) Grev.	*		BM,Wc,Ws	sublittoral zone. 3-20 m depth on rocks and shells [O].
Asperococcus fistulosus (Huds.) Hook.	BC			
Ascophyllum nodosum (L.) Le Jol.	D,La			
Chaetopteris plumose Kutz.			SC	deep water.
Chorda filum (L.) Stackh.	SC,D,La	H,BC		2-9 m depth on rocks and bivalves, often with eelgrass [0].
Chorda tomentosa Lyngb.		H,BC		2-9 m depth on rocks, *Fucus*, and bivalves.
Chordaria flagelliformis (O.F. Müll.) C. Ag.	SC,H,BC,La	H,BC		low intertidal to 18 m depth on rocks, bivalves, other algae and eelgrass.
Cladosiphon zosterae (J. Ag.) Kylin	BC			
Coilodesme bulligera Strömf.		BC		
Desmarestia aculeata (L.) Lamour.	SC	BC	BM,Wc,SC	1-25 m depth on rocks or loose-lying on mud; in Hudson Bay deep water, common.

SPECIES	JAMES BAY MARINE REGION		HUDSON BAY MARINE REGION	COMMENTS ON OCCURRENCE
	James Bay	southeastern Hudson Bay		
Desmotrichum undulatum (J. Ag.) Rinncke	H			2-15 m depth on rocks or other algae [R].
Dictyosiphon foeniculaceus (Huds.) Grev.	H,BC	BC	BM	2-18 m depth on rocks, other algae, and possibly as loose-lying populations [F].
Dictyosiphon chordaria Aresch		BC		
Ectocarpus siliculosis (Dillw.) Lyngb.	H,BC	H,BC		at depth of 2-9 m on *Fucus* [F].
Elachista fucicola (Vell.) Aresch.	SC,BC	H,BC,L		2-30 m depth, epiphytic on other algae [F].
Elachista lubrica Rupr.	*	BC		
Eudesme virescens (Carm. ex Harv. in Hook) J. Ag.		H,BC		2-6 m depth on rocks [R].
Fucus distichus (L.)	D. La			
Fucus distichus edentatus (Pyl.) Powell	SC,S,BC	RI,BC		intertidal on rocks [F].
Fucus distichus evanescens (C. Ag.) Powell	H,BC,L	H,BC	BM,SC	intertidal to 10 m depth on rocks [F]; dwarf form.
Fucus vesiculosus (L.)			BM,Ws	
Halopteris scoparia (L.) Sauv.		BC		
Haplospora globosa Kjellm.		H		floating in Long Island Sound, generally loose-lying or attached to rocks at depth of 2-20 m.
Laminaria agardhii Kjellm.			BM	sublittoral zone to deep water.
Laminaria digitata Lamour.			BM	deep water.
Laminaria longicruris Pyl.		BC	BM	3-14 m depth on rocks [O]; in Hudson Bay deep water in sheltered places.
Laminaria saccharina (L.) Lamour	BM,BC	BC		3-14 m on rocks, pebbles, and shells [F].
Lithoderma sp.		BC		
Litosiphon filiformis (Reinke) Batt.		BC		epiphytic on *Laminaria*.
Myriomema strangulans Grev.	H			18 m depth at Grey Goose I.
Pylaiella littoralis (L.) Kjellm.	BC,L	BC,L	BM,Wc	intertidal to 15 m depth on rocks, ascidacians, and other algae (e.g., *Fucus*) [F].
Ralfsia fungiformis (Gunn.) Setch. and Gard.	H			3-10 m depth on rocks and *Laminaria*.
Petalonia fascia (O.F. Müll.) Kuntze	H	H		5-18 m depth in James Bay.
Scytosiphon lomentaria (Lyngb.) Link		BC		
Sphacelaria cirrosa (Roth) C. Ag.		H		18 m depth at Grey Goose I.
Sphacelaria plumosa Lyngb.	SC,H,BC,L	H,BC		20-30 m depth on rocks, *Ahnfeltia plicata*, and *Laminaria*, also intertidal on pebbles [F].
Sphacelaria radicans (Dillw.) C. Ag.		H		at 18 m depth in SE. Hudson Bay.
Sphaerotrichia divaricata (C. Ag.) Kylin		BC		
Stictosiphon subsimplex Hold		BC		
Stictosiphon tortilis (Rupr.) Reinke	H	H		4-20 m depth, loose-lying or on rocks, *Laminaria*, or *Fucus* [F].
Cl. Rhodophyceae (red algae) - multicellular, attached, relatively large.				
Ahnfeltia plicata (Huds.) Fries	SC,H,BM,BC	H,S,BC		3-18 m depths on rocks and loose-lying, also intertidal in Hudson Bay.
Antithamnion sp.			BM	
Antithamnion boreale (Gobi) Kjellm	SC,H	H		2-15 m depths on rocks, hydroids, and other algae [O].

SPECIES	JAMES BAY MARINE REGION		HUDSON BAY MARINE REGION	COMMENTS ON OCCURRENCE
	James Bay	southeastern Hudson Bay		
Clathromorphum compactum (Kjellm.) Foslie		H		2-15 m depths on rocks and shells of limpets and bivalves [O].
Clathromorphum circumscriptum (Strömf.)		BC		
Delesseria sinuosa (Good and Wood.)			BM	
Dumontia incrassata (O.F. Mull.) Lamour.	H			3-5 m depths on mud [R].
Erythrotrichia carnea (Dillw.) J. Ag.	H			5-6 m depths at Charlton I.
Euthora cristata (L.) J. Ag.			SC	
Harveyella mirabilis (Dillw.) J. Ag.	SC			2-35 m depths, parasitic on *Rhodomela lycopodioides* [O].
Lithothamniun sp.			BM	
Lithothamniun glaciale Kjellm.		H		2-15 m on rocks [O].
Lithothamniun lemoineae Adey		BC		
Membranoptera alata Huds.) Stackh.	SC			
Neodilsea integra Kjell.,) A. Zin.	BC,L	H,BC		2-25 m on rocks or loose-lying on mud [F].
Odonthalia dentata (L.) Lyngb.	H,BM,BC,L	H,BC	BM,SC	15 m to shallower depths on rocks and loose-lying on mud [O].
Odonthalia floccosa (Esper.) Falk.	•			
Palmaria palmata (L.) O. Kuntze	SC,H,BM,BC			2-5 m on rocks, *Fucus*, and *Laminaria* [O].
Peyssonelia johansenii Howe	H			"on stones at low tide".
Phycodrys rubens (L.) Batt.	SC,H,BM,BC	H,BC		2-25 m depths on rocks or other algae.
Phyllophora brosiaei f. pygmaea Darb.?			BM	
Phyllophora truncata (Pallas) A. Zin.	SC	H		2-25 m depths loose-lying on mud or attached to rocks, *Laminaria*, or polychaete cases, usually in dense populations [F].
Phymatolithon laevigatum (Fosl.) Fosl.		H		
Polyides rotundus (Huds.) Grev.	BC			
Polysiphonia sp.			BM	
Polysiphonia arctica J. Ag.	H,BC	H,BC		2-30 m depths on rocks, other algae, or loose-lying on mud [F].
Polysiphonia nigrescens (Huds.) Grev.	BC	BC		
Polysiphonia ureolata (Light. ex Dillw.) Grev.	H,BC	BC	BM	5 m depths at Charlton Island.
Porphyra laciniata (Lightf.) Ag.			BM	
Ptilota pectinata (Gunn.) Kjellm. = P. serrata	SC		BM,SC	
Rhodochorton sp.	BC			
Rhodomela confervoides (Huds.) Silva	BC	BC		
Rhodomela lycopodioides (L.) C. Ag.	SC,H,BC,L	H,BC		2-35 m depths on rocks or, less commonly, other algae, or loose-lying on mud [F].
Rhodomela subfusca (Woodw.) Ag.			SC	
Rhodymenia palmate (L.) Grev.			BM	
Turnerella pennyi (Harv.) Schm.		H		7-25 m on rocks [O].
Cl. Xanthophyceae (yellow-green algae) filamentous				
Vaucheria sp.		BC		

References and collections:

SC = Setchell and Collins 1908 (JAMES BAY: general area; HUDSON BAY: Depot Island).
H = Howe 1927 (JAMES BAY: Charlton Island, Grey Goose Island, Old Factory Bay, Halfway Point; SOUTHEASTERN HUDSON BAY: Richmond Gulf, between Richmond Gulf and Great Whale River, between Otsaka Harbour and Black Whale Harbour, and Long Island Sound).
BM = Bell and MacFarlane 1933 (JAMES BAY: Charlton Island; HUDSON BAY: no specific locations).
W = Whelden 1947 (HUDSON BAY: Chesterfield Inlet=Wc, Southampton Island=Ws).
BC = Breton-Provencher and Cardinal 1978 (JAMES BAY: Rupert Bay, Eastmain Estuary; SOUTHEASTERN HUDSON BAY: Manitounuk Sound).
* = Breton-Provencher and Cardinal 1978 (JAMES BAY: general area; collector not listed).
L = Lee 1980 (JAMES BAY: Ekwan River, Moose River, and Swan River).
La = Lalumière et al. 1994 (JAMES BAY: La Grande River area).
S = Savile in Lee 1980 (SOUTHEASTERN HUDSON BAY: Great Whale River area).
Rl = Riley in Lee 1980 (JAMES BAY: Moose River area).
D = Dignard et al. 1991 (JAMES BAY: eastern James Bay).

Frequency of occurrence in collections:

Designations follow Lee (1980) except where Breton-Provencher and Cardinal (1978) found species to occur in more than 40% of the stations sampled in the region, in which case the frequency of occurrence was changed from occasional to frequent.
[R] = rare
[O] = occasional
[F] = frequency

APPENDIX 2 A PARTIAL LISTING OF INVERTEBRATES AND UROCHORDATES OF THE JAMES BAY, HUDSON BAY, HUDSON STRAIT, AND FOXE BASIN MARINE REGIONS. UPDATED FROM STEWART et al. (1993).

Symbols are explained, and references listed, at the end of the Appendix 2 on page A-28.

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
ANNELIDA: Oligochaeta				
Amphichaeta leydigi	-	P	-	-
Bratislavia unidentata	-	P	-	-
Chaetogaster diaphanus	-	P	-	-
[1] *Limnodrilus hoffmeisteri*	-	P	-	-
[1] *Limnodrilus udekemaianus*	-	P	-	-
Limnodrilus profundicola	-	P	-	-
Nais behningi	-	P	-	-
Nais communis	-	P	-	-
Nais pseudobtusa	-	P	-	-
Nais simplex	-	P	-	-
Nais variabilis	-	P	-	-
Paranais litoralis	-	P	-	-
Pristina aequiseta	-	P	-	-
Slavina appendiculata	-	P	-	-
Specaria josinae	-	P	-	-
Tasserkidrilus kessleri	-	P	-	-
Tubifex tubifex	-	P	-	-
Uncinais uncinata	-	P	-	-
Vejdovskyella intermedia	-	P	-	-
ANNELIDA: Polychaeta				
Aglaophamus malmgreni Theel	P	-	P	-
Aglaophamus neotenus Noyes	P	-	-	-
Aglaophamus rubella (Hartman)	P	-	-	-
Ammotrypane aulogaster	-	P	P	P
Ammotrypane breviata	-	-	P	-
Ammotrypane cylindricaudatus	-	P	-	-
Ampharete acutifrons	P	P	P	-
Ampharete goesi	-	-	P	-
Amphicteis sundevalli	P	-	-	-
Amphitrite cirrata	-	P	P	-
Amphitrite groenlandica	-	P	-	-
Amphitrite johnstoni	-	P	-	-
Anobothrus gracilis	-	P	-	-
Antinoella badia	P	P	-	-
Antinoella sarsi	P	-	-	P
Arenicola marina (Linnaeus)	-	P	P	-
Aricidea catherinae (McIntosh)	-	-	P	-
Aricidea suecica Eliason	P	-	P	-
Artacama proboscidea	P	P	P	-
Asabellides sibirica	P	-	P	-
Asabellides sp.	-	P	-	-
Autolytus alexandri	-	P	-	-
Autolytus prismaticus O.F. Muller	P	-	-	-
Autolytus prolifer	-	-	P	-
Axiothella catenata	-	P	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Capitella capitata (Fabricius)	P	P	P	-
Ceratocephala loveni Malmgren	-	-	P	-
Chaetozone setosa	P	-	P	P
Chaetozone sp.	-	P	-	-
Chitinopoma fabricii	-	-	P	P
Chone duneri Malmgren	-	-	P	-
Chone infundibuliformis Kroyer	-	P	P	-
Chone sp.	P	-	-	P
Cirratulus cirratus	-	P	-	-
Cossura longocirrata	P	P	-	-
Diplocirrus glaucus	P	-	-	-
Ephesiella minuta	-	-	P	-
Ephesiella peripatus	P	-	-	-
Eteone flava (Fabricius)	-	-	P	-
Eteone longa (Fabricius)	P	P	P	P
Euchone analis	-	P	-	P
Euchone incolor Hartman	-	-	P	-
Euchone papillosa	P	P	P	P
Eucranta villosa	-	P	-	-
Eulalia sp.	-	P	-	-
Eumida sp.	-	P	-	-
Euphrosine borealis Oersted	-	P	P	-
Eusyllis blomstrandi	-	P	P	P
Exogone verugera (Claparede)	P	-	P	-
Fabricia sabella	-	-	P	-
Flabelligera affinis M. Sars	-	P	-	P
Gattyana cirrosa	-	P	P	P
Glycera capitata Oersted	-	-	P	-
Harmothoe extenuata (Grube)	P	P	P	P
Harmothoe imbricata (Linnaeus)	P	P	P	P
Harmothoe nodosa (G.O. Sars)	-	P	P	P
Heteromastus sp.	P	-	-	-
Lagisca rarispina (G.O. Sars)	-	P	-	-
Lanassa venusta	P	P	P	P
Laonice cirrata	-	P	-	-
Laonome kroyeri	P	-	-	-
Leaena abranchiata	-	-	-	P
Leiochone polaris	P	-	-	-
Lepidametria commensalis	-	P	-	-
Lepidonotus sp.	-	P	-	-
Lumbrineris fragilis (O.F. Muller)	P	P	P	-
Lumbrineris impatiens (Claparede)	-	-	P	-
Lumbrineris latreilli (Audouin & Milne-Edwards)	-	-	P	-
Lumbrineris minuta Theel	P	P	P	-
Lysilla loveni	-	P	-	-
Lysippe labiata	-	-	P	-
Maldane sarsi Malmgren	P	P	P	-
Manayunkia aestuarina	-	P	-	-
Melinna cristata (M. Sars)	P	P	-	-
Micronephthys minuta	P	-	P	P
Myriochele heeri	-	P	-	-
Myriochele oculata Zachs	P	P	P	-
Mystides borealis	P	-	-	P

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Nephtys ciliata O.F. Muller	P	P	P	P
Nephtys longosetosa Oersted	-	P	-	-
Nephtys paradoxa	-	P	-	-
Nereimyra aphroditoides	P	-	P	P
Nereis pelagica (Linnaeus)	-	P	P	P
Nereis virens	-	P	-	-
Nereis zonata Malmgren	-	P	P	-
Nichomache lumbricalis (Fabricius)	-	P	P	-
Nichomache quadrispinata	-	P	-	-
Nicolea zostericola	P	P	P	-
Notomastus latericeus	P	P	-	-
Onuphis conchylega (M. Sars)	-	P	P	P
Ophelia aulogaster Rathke	-	-	P	-
Ophelia cylindrocaudata A. Hansen	-	-	P	-
Ophelia limacina (Rathke)	-	P	P	-
Ophryotrocha littoralis?	-	P	-	-
Owenia fusiformis	-	P	P	-
Owenia oculata Zachs	-	-	P	-
Paraonis sp.	P	-	P	-
Pectinaria granulata (Linnaeus)	P	P	P	-
Pectinaria hyperborea Malmgren	P	P	P	P
Petaloproctus tenuis	P	P	P	-
Pherusa plumosa	-	P	-	-
Pholoe minuta	P	P	P	P
Phyllodoce groenlandica Oersted	-	P	P	-
Phyllodoce mucosa	-	-	P	-
Pionosyllis compacta	-	P	P	P
Pista maculata (Dalyell)	P	P	-	P
Polycirrus medusa	-	-	P	P
Polydora caeca	P	-	-	-
Polydora caulleryi	-	-	P	-
Polydora quadrilobata	-	-	P	-
Polydora sp.	-	P	-	P
Potamilla neglecta (Sars)	-	-	P	-
Praxillella praetermissa (Malmgren)	-	P	P	-
Prionospia cirrifera Wiren	-	-	P	-
Prionospia steenstrupi Malmgren	P	-	P	-
Proceraea sp.	-	P	-	-
Proclea graffi	-	-	-	P
Pygospio elegans	-	P	P	P
Rhodine gracilior (Tauber)	P	-	P	-
Sabella crassicornis	P	-	P	-
Sabellides borealis	P	P	-	-
Sabellides octocirrata	P	-	P	P
Scalibregma inflatum Rathke	P	P	P	-
Scolelepis sp.	P	-	-	-
Scoloplos armiger (O.F. Muller)	P	P	P	-
Sphaerodorum gracile (Rathke)	-	-	P	-
Spio sp.	-	P	-	-
Spio filicornis	P	-	-	-
Spirorbis granulatus?	-	P	-	-
Spirorbis spirillum (Linnaeus)	-	P	P	P
Stauronereis caecus	-	-	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Syllis cornuta Rathke	-	-	P	-
Syllis fasciata	-	P	P	P
Syllis gracilis Grube	-	-	P	-
Tauberia gracilis Tauber	-	-	P	-
Terebellides stroemi M. Sars	P	P	P	-
Tharyx acutus	P	P	P	P
Thelepus cincinnatus	-	-	P	P
Travisia forbesi	-	-	P	-
Travisia sp.	-	P	-	-
ARTHROPODA: Amphipoda				
Acanthonotozoma cristatum	-	-	-	P
Acanthonotozoma inflatum (Kroyer)	P	P	P	P
Acanthonotozoma serratum (O. Fabr.)	-	-	P	P
Acanthonotozoma sp.	-	P	-	-
Acanthostepheia malmgreni	P	P	P	P
Aceroides latipes G.O. Sars	P	-	P	P
Aceros phyllony	P	-	-	-
Andaniexis abyssi	-	P	-	-
Aeginina longicornis (Kroyer)	-	-	P	P
Ampelisca eschrichti Kroyer	P	P	P	P
Ampelisca latipes Stephensen	-	-	P	-
Ampelisca macrocephala Lilljeborg	P	P	P	-
Amphithopsis longicaudata Boeck	P	-	P	-
Anonyx affinis	-	-	P	P
Anonyx compactus Gurjanova	-	P	-	-
Anonyx laticoxae Gurjanova	-	P	P	P
Anonyx lilljeborgi Boeck	-	P	P	P
Anonyx makarovi	P	-	P	P
Anonyx nugax (Phipps)	P	P	P	P
Anonyx pacificus Gurjanova	-	P	-	-
Anonyx sarsi Steele and Brunel	P	P	P	P
Apherusa glacialis H.J. Hansen	-	P	P	P
Apherusa megalops (Buchholtz)	-	P	P	P
Arctopleustes glabricauda	-	P	P	-
Argissa hamatipes	-	-	-	P
Aristias tumidus (Kroyer)	-	-	P	P
Arrhinopsis longicornis	-	-	-	P
Arrhis phyllonyx (M. Sars)	P	-	P	-
Atylus carinatus (Fabricius)	P	-	P	P
Atylus smitti	-	-	P	P
Atylus sp.	-	P	-	-
Bathymedon obtusifrons (H.J. Hansen)	-	-	P	P
Boeckosimus affinis	P	-	P	-
Boeckosimus edwardsi (Kroyer)	P	P	P	P
Boeckosimus normani	-	P	-	-
Boeckosimus plautus	P	P	P	P
Byblis gaimardi (Kroyer)	P	P	P	P
Calliopius laeviusculus (Kroyer)	P	P	P	-
Calliopius rathkei	P	P	-	-
Caprella linearis	-	-	-	P
Caprella septentrionalis (Kroyer)	P	P	P	P
Caprella sp.	-	P	-	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Centromedon pumilus	-	-	-	P
Corophium clarencense	-	P	-	-
Corophium crassicorne Burzelius	P	-	-	-
Dulichia arctica	P	-	-	-
Dulichia porrecta (Bate)	P	P	P	-
Dulichia spinosissima Kroyer	P	-	-	P
Dulichia ? tuberculata Boeck	-	-	P	-
Dyopedos hirticornis	-	-	-	P
Dyopedos monacanthus	P	-	-	-
Dyopedos porrectus	P	P	P	-
Ericthonius tolli Bruggen	P	P	P	P
Eurystheus melanops (G.O. Sars)	-	P	P	P
Eusirus cuspidatus Kroyer	P	P	P	P
Gammaracanthus loricatus (Sabine)	P	P	P	P
Gammarellus homari (J.C. Fabr.)	-	P	P	-
Gammaropsis maculata	-	P	P	P
Gammarus oceanicus Segerstrale	P	P	P	P
Gammarus setosus Dementieva	P	P	P	P
Gammarus wilkitzkii Birula	P	P	P	P
Gitanopsis arctica G.O. Sars	-	P	P	-
Goesia depressa (Goes)	-	-	P	-
Guernia nordenskioldi (H.J. Hansen)	-	-	P	-
Halegonis sp.	-	P	P	-
Halirages fulvocinctus (M. Sars)	P	P	P	P
Halirages mixtus Stephensen	-	-	P	-
Halirages nilssoni	P	-	P	P
Haliragoides inermis (Sars)	P	P	-	-
Haploops laevis	P	-	-	-
Haploops setosa Boeck	P	-	P	P
Haploops tubicola Lilljeborg	P	P	P	P
Harpinia serrata	-	P	-	-
Hippomedon abyssi	P	P	-	-
Hippomedon propinquus	P	-	-	-
Hyperia galba (Montague)	P	P	P	-
Hyperia medusarum (O.F. Muller)	P	-	P	-
Hyperia spingera Bovallius	-	-	P	-
Hyperoche medusarum (Kroyer)	P	P	P	-
Ischyrocerus anguipes Kroyer	P	P	P	P
Ischyrocerus assimilis	P	-	-	-
Ischyrocerus commensalis Chevreux	P	-	P	-
Ischyrocerus inaequistylis	-	P	-	-
Ischyrocerus latipes Kroyer	P	P	P	P
Ischyrocerus latipes var *assimilis*	-	-	P	-
Ischyrocerus megacheir (Boeck)	-	P	P	-
Ischyrocerus megalops G.O. Sars	P	P	P	P
Ischyrocerus nanoides (H.J. Hansen)	-	-	P	-
Ischyrocerus stephenseni	-	-	-	-
Jassa sp.	P	-	-	-
Laetmatophilus armatus (Norman)	-	-	P	-
Lysianopsis sp.	-	P	-	-
Maera loveni	-	-	-	P
Melita formosa	P	-	-	P
Melita dentata (Kroyer)	P	P	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Melita quadrispinosa	-	-	-	P
Melphidippa goesi	-	P	-	P
Melphidippa sp.	P	-	-	-
Mesometopa neglecta	-	-	P	P
Metacaprella horrida	-	-	-	P
Metopa alderi (Sp. Bates)	-	-	P	-
Metopa borealis (G.O. Sars)	-	P	P	-
Metopa bruzelii (Goes)	P	P	P	P
Metopa cariana Gurjanova	-	-	P	-
Metopa clypeata	-	-	P	-
Metopa glacialis	-	-	P	P
Metopa hearni Dunbar	-	-	P	-
Metopa invalida G.O. Sars	P	P	P	-
Metopa longicornis Boeck	-	-	P	-
Metopa longirama Dunbar	-	-	P	-
Metopa nordmanni Stephensen	-	-	P	-
Metopa norvegica (Lillj.)	-	-	P	-
Metopa propinqua G.O. Sars	-	-	P	-
Metopa robusta	-	-	P	-
Metopa sinuata G.O. Sars	-	-	P	-
Metopella angusta	-	P	-	-
Metopella carinata (H.J. Hansen)	-	-	P	P
Metopella longimana (Boeck)	-	-	P	P
Metopella nasuta (Boeck)	-	-	P	-
Metopella neglecta (H.J.Hansen)	-	-	P	-
Metopelloides micropalma	-	-	P	-
Metopelloides zernovi	-	-	P	-
Monoculodes boecki	-	-	-	P
Monoculodes borealis	-	P	-	P
Monoculodes edwardsi Holmes	P	-	P	-
Monoculodes intermedius	-	-	-	P
Monoculodes latimanus (Goes)	-	P	P	P
Monoculodes longirostris (Goes)	-	-	P	-
Monoculodes schneideri	-	-	-	P
Monoculodes simplex	-	-	-	P
Monoculodes tuberculatus Boeck	-	-	P	P
Monoculodes vibei	-	P	-	P
Monoculodes zernovi	-	-	-	P
Monoculopsis longicornis	P	P	-	P
Neohela maxima	P	P	-	-
Neopleustes assimilus	P	-	-	-
Neopleustes boecki	-	-	P	-
Neopleustes pulchellus	-	P	P	-
Odius carinatus (Sp. Bate)	-	-	P	-
Oediceros saginatus Kroyer	P	P	P	P
Onisimus affinis H.J. Hansen	-	-	P	-
Onisimus edwardsi (Kroyer)	-	-	P	-
Onisimus glacialis G.O. Sars	P	P	P	P
Onisimus litoralis (Kroyer)	P	P	P	P
Onisimus nanseni G.O. Sars	-	P	P	P
Onisimus plautus (Kroyer)	-	-	P	-
Opisa eschrichti	-	-	P	-
Oradarea longimana	-	-	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Orchomene macroserrata Shoemaker				
Orchomenella groenlandica (H.J. Hansen)	-	P	P	P
Orchomenella minuta (Kroyer)	-	P	P	-
Orchomenella pinguis (Boeck)	P	P	P	P
Paradalisca cuspidata Kroyer	P	P	P	P
Paramphithoe hystrix (J.C. Ross)	-	-	P	-
Parapleustes assimilis (G.O. Sars)	-	P	P	P
Parapleustes bicuspis (Kroyer)	P	P	P	P
Parapleustes boecki (H.J. Hansen)	-	P	P	P
Parapleustes glabricauda Dunbar	-	-	P	-
Parapleustes gracilis	-	-	P	-
Parapleustes pulchellus (Kroyer)	-	-	-	P
Parapleustes ramyslovi	-	-	P	-
Parapleustes sinuipalma Dunbar	-	-	-	P
Pardalisca cuspidata	-	-	P	-
Paroediceros lynceus (M. Sars)	P	-	P	P
Paronesimus barentsi Stebbing	P	P	P	P
Photis tenuicornis G.O. Sars	P	-	P	P
Photis sp.	-	-	P	-
Phoxocephalus holbolli (Kroyer)	-	-	-	P
Pleustes medius (Goes)	-	-	P	-
Pleustes panoplus (Kroyer)	-	-	P	P
Pleusymtes buttoni	P	-	P	P
Pleusymtes glabroides	-	-	P	-
Pontogeneia inermis (Kroyer)	-	-	P	-
Pontoporeia affinis Lindstrom	P	P	P	P
Pontoporeia femorata (Kroyer)	-	P	P	-
Protomedeia fasciata Kroyer	P	P	P	P
Protomedeia grandimana Bruggen	-	P	P	-
Pseudalibrotus glacialis G.O. Sars	-	-	P	P
Pseudalibrotus litoralis Kroyer	-	-	P	-
Pseudalibrotus nanseni G.O. Sars	P	-	P	-
Rhachotropis aculeata (Lepechin)	-	-	P	-
Rhachotropis inflata (G.O. Sars)	P	P	P	P
Rhachotropis oculata	-	-	P	-
Rozinante fragilis (Goes)	P	P	P	P
Siphonoecetes typicus Kroyer	P	-	-	P
Sivladia arctica	-	-	P	-
Socarnes bidenticulatus (Bate)	-	-	-	P
Socarnes vahli (Kroyer)	-	-	P	P
Stegocephalopsis ampulla (Phipps)	-	P	P	P
Stegocephalus inflatus (Kroyer)	-	-	P	-
Stenopleustes olriki	P	-	P	P
Stenopleustes pulchellus	-	-	-	P
Stenothoe brevicornis G.O. Sars	P	-	-	-
Stenula nordmanni	-	-	P	-
Stenula sp.	-	-	P	-
Sympleustes buttoni Dunbar	P	-	-	-
Sympleustes olriki H.J. Hansen	-	-	P	-
Sympleustes glabroides Dunbar	-	-	P	-
Syrrhoe crenulata Goes	-	-	P	-
[2]*Themisto abyssorum* (Boeck)	P	P	P	P
[2]*Themisto compressa* Goes	P	P	P	-
	-	P	-	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
[2]*Themisto gaudichaudi*	-	-	P	P
[2]*Themisto gracipiles*	-	-	P	-
[2]*Themisto libellula* (Lichtenstein)	P	P	P	P
Tiron spiniferum (Stimpson)	-	-	P	-
Tmetonyx acutus	-	P	-	-
Tmetonyx cicada (Fabricius)	P	P	-	-
Tmetonyx orchomenoides Stephensen	-	-	P	-
Tryphosa marina	-	-	P	P
Tryphosella orchomenoides	-	P	P	-
Tryphosella triangula	-	P	-	-
Unicola laticornis Hansen	-	-	P	-
Unicola leucopis (Kroyer)	P	P	P	P
Westwoodilla brevicalar (Goes)	-	-	P	P
Westwoodilla megalops (G.O. Sars)	P	P	P	P
Weyprechtia pinguis (Kroyer)	P	P	P	P
ARTHROPODA: Cirripedia				
Balanus balanoides	P	P	P	P
Balanus balanus (Linnaeus)	P	P	P	P
Balanus crenatus Burguiere	P	P	P	P
Cypris sp.	P	-	-	-
Scalpellum cornutum	-	-	P	P
Scalpellum hamatum	-	-	-	P
ARTHROPODA: Copepoda				
Acartia bifilosa (Giesbrecht)	-	P	-	-
Acartia clausi Giesbrecht	P	P	-	-
Acartia longiremis (Lilljeborg)	P	P	P	-
Ameira longipes Boeck	P	P	-	-
Bradyidius similis	-	P	P	-
Bradypontius magniceps (Brady)	-	P	-	-
Calanus finmarchicus (Gunnerus)	-	P	P	P
Calanus glacialis Yaschnov	P	P	P	P
Calanus hyperboreus Kroyer	P	P	P	P
Calanus plumchrus Marukawa	-	P	-	-
Centropages abdominalis Sato	P	P	-	-
Centropages hamatus	P	P	P	-
Clausocalanus arcuicornis (Dana)	-	P	-	-
Corycaeus anglicus Lubbock	-	P	-	-
Cyclopina gracilis Claus	P	P	-	-
Cyclopina sp.	P	-	P	-
Dactylopodia tisboides (Claus)	-	P	-	-
Dactylopodia vulgaris (G.O. Sars)	-	P	-	-
Danielssenia sp.	P	-	-	-
Derjuginia tolli (Linko)	P	P	-	-
Dermatomyzon nigripes (Brady)	P	-	-	-
Diaptomus pribilofensis	-	P	-	-
Diaptomus sp.	P	-	-	-
Ectinosoma melaniceps Boeck	P	-	-	-
Epischura lacustris	-	P	-	-
Epischura nevadensis	-	P	-	-
Euchaeta arctica	-	-	P	-
Euchaeta glacialis Hansen	P	-	-	-

Species	**James Bay (includes S.E. Hudson Bay)**	**Hudson Bay**	**Hudson Strait**	**Foxe Basin**
Euchaeta norvegica Boeck	P	P	P	-
Euryte longicaudata Philippi	P	-	-	-
Eurytemora affinis	-	P	-	-
Eurytemora americana Williams	P	P	-	-
Eurytemora herdmani Thompson and Scott	P	P	-	-
Eurytemora raboti	-	P	-	-
Halectinosoma sp.	P	-	-	-
Harpacticus chelifer	-	P	-	-
Harpacticus superflexus Willey	P	-	-	-
Harpacticus uniremus Kroyer	P	P	-	-
Heterolaophonte discophora (Willey)	P	-	-	-
Laophonte elongata Boeck	-	P	-	-
Laophonte sp.	P	-	-	-
Limnocalanus macrurus G.O. Sars	-	P	-	-
Metridia lucens	-	P	-	-
Metridia longa (Lubbock)	P	P	P	-
Microcalanus sp.	-	-	P	-
Microcalanus pygmaeus (G.O. Sars)	P	P	-	-
Macrocherion sp.	-	P	-	-
Monstrilla sp.	-	P	-	-
Monstrilla dubia Scott	P	-	-	-
Nitocra spinipes	P	-	-	-
Oithona similis Claus	P	P	P	-
Oithona spinirostris Claus	-	P	-	-
Oncaea borealis G.O. Sars	P	P	-	-
Oncaea venusta Philippi	-	P	-	-
Onchocamptus horrida (Norman)	P	-	-	-
Paracalanus parvus (Claus)	-	P	-	-
Paralaophonte perplexa (Scott)	-	P	-	-
Parartotrogus arcticus Scott	P	-	-	-
Parathalestris croni (Kroyer)	P	-	-	-
Platychelipus littoralis Brady	P	-	P	-
Pseudalibrotus minutus	-	-	-	P
Pseudobradya minor (T. and A. Scott)	-	P	-	-
Pseudobradya sp.	P	-	-	-
Pseudocalanus acuspes	P	-	-	-
Pseudocalanus minutus (Kroyer)	P	P	-	-
Pseudocalanus newmani	P	-	-	-
Pseudocalanus sp.	-	-	P	-
Pseudocyclops obtusatus (Brady and Robertson)	-	P	-	-
Rhynchothalestris helgolandica (Claus)	P	-	-	-
Robertsonia tenuis Brady	-	P	-	-
Stenhelia gibba Boeck	P	-	-	-
Stephos sinuatus Willey	P	-	-	-
Tachidius discipes Giesbrecht	P	-	-	-
Tegastes falcatus (Norman)	P	-	-	-
Tegastes nanus G.O. Sars	P	-	-	-
Thalestris brunnea G.O. Sars	P	-	-	-
Tisbe furcata (Baird)	P	P	-	-
Tisbe gracilis (Scott)	-	P	-	-
Tortanus discaudatus (Thompson and Scott)	P	P	-	-
Undinula darwini (Lubbock)	-	P	-	-
Xanthocalanus sp.	-	-	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Zaus abbreviatus G.O. Sars	-	P	-	-
Zaus spinatus Goodsir	P	P	-	-
Zoisme typica Boeck	-	P	-	-
ARTHROPODA: Cumacea				
Brachydiastylis resima (Kroyer)	P	P	-	P
Campylaspis rubicunda (Lilljeborg)	-	-	P	-
Cumella carinata (Hansen)	-	-	P	-
Cumella sp.	-	-	-	P
Diastylis edwardsi (Kroyer)	P	-	-	-
Diastylis goodsiri (Bell)	P	P	P	P
Diastylis quadrispinosa	-	P	-	-
Diastylis rathkei (Kroyer)	P	P	P	P
Diastylis scorpioides (Lepechin)	P	P	P	P
Diastylis spinulosa	P	-	-	P
Diastylis sulcata Calman	P	-	-	-
Eudorella emarginata (Kroyer)	P	-	-	-
Hemilamprops cristata G.O. Sars	P	-	-	-
Hemilamprops uniplicata (G.O. Sars)	-	-	P	-
Lamprops fuscata G.O. Sars	P	P	-	P
Lamprops quadriplicata	-	P	-	-
Leptostylis ampullacea	-	-	-	P
Leucon nasica (Kroyer)	P	-	-	-
Leucon nasicoides (Lilljeborg)	-	P	P	-
Leucon pallidus G.O. Sars	-	-	P	-
Leucon sp.	-	-	-	P
Platyaspis typica (G.O. Sars)	-	-	P	-
ARTHROPODA: Decapoda				
Argis dentata (Rathbun)	P	P	P	P
Atelecyclus sp.	-	P	-	-
Eualus fabricii (Kroyer)	P	P	P	P
Eualus gaimardi (H. Milne-Edwards)	P	P	P	P
Eualus gaimardi belcheri	-	P	P	-
Eualus macilentus (Kroyer)	P	-	P	-
Hyas coarctatus Leach	P	P	P	P
Lebbeus groenlandicus (Fabricius)	P	P	P	P
Lebbeus microceros	-	-	-	P
Lebbeus polaris (Sabine)	P	P	P	P
Pagurus pubescens (Kroyer)	P	P	P	P
Pandalus borealis Kroyer	-	-	P	-
Pandalus montagui Leach	P	P	P	-
Pasiphaea tarda Kroyer	-	-	P	-
Sabinea septemcarinata (Sabine)	P	P	P	P
Sclerocrangon boreas (Phipps)	P	P	P	P
Sergestes arcticus Kroyer	-	-	P	-
Spirontocaris lilljeborgi (Danielssen)	-	-	P	-
Spirontocaris phippsi (Kroyer)	P	P	P	P
Spirontocaris spinus (Sowerby)	P	P	P	P
ARTHROPODA: Euphausiacea				
Meganyctiphanes norvegica M. Sars	-	-	P	-
Thysanoessa inermis (Kroyer)	-	-	-	P

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Thysanoessa longicaudata (Kroyer)	?	P	-	-
Thysanoessa raschii (M. Sars)	P	P	P	-
ARTHROPODA: Isopoda				
Aega psora	-	-	P	-
Arcturus baffini (Sabine)	-	P	P	P
Bopyroides hippolytes	-	-	P	-
Calathura brachiata	-	-	-	P
Ilyarachna hirticeps G.O. Sars	-	-	P	-
Janira tricornis	-	-	P	P
Mesidotea entomon (Linnaeus)	-	-	P	-
Mesidotea sabini (Kroyer)	P	P	P	P
Munna fabricii	-	P	-	-
Munna kroyeri	-	P	-	-
Munnopsis typica	P	P	P	P
Munnopsurus giganteus	P	-	-	P
Phryxus abdominalis	-	-	-	P
Synidotea marmorata	-	-	P	P
Synidotea nodulosa (Kroyer)	P	-	-	-
ARTHROPODA: Mysidacea				
Boreomysis nobilis G.O. Sars	-	-	P	-
Erythrops erythrophalma	-	P	P	-
Meterythrops robusta	P	P	P	-
Mysis litoralis (Banner)	P	P	P	-
Mysis mixta Lilljeborg	P	-	P	-
Mysis oculata (Fabricius)	P	P	P	P
Mysis polaris Holmquist	-	-	P	-
ARTHROPODA: Nebaliacea				
Nebalia bipes	P	-	P	P
ARTHROPODA: Ostracoda				
Acetabulostomata sp.	-	P	P	-
Conchoecia sp.	P	P	P	-
Cyprideis sorbyana	P	-	-	-
Cythereis dunelmensis	P	-	-	-
Hemicythere quadridentata	-	-	P	-
Philomedes sp.	-	P	-	-
Philomedes globosus (Lilljeborg)	P	-	P	P
ARTHROPODA: Pycnogonida				
Boreonymphon abyssorum	-	-	-	P
Colossendeis proboscidea (Sabine)	-	-	-	P
Eurycyde hispida (Kroyer)	-	P	-	-
Nymphon brevitarse Kroyer	P	P	P	P
Nymphon elegans Hansen	-	-	-	P
Nymphon grossipes Kroyer	-	-	P	P
Nymphon hirtipes Bell	P	P	P	P
Nymphon hirtum Kroyer	-	-	-	P
Nymphon longitarse Kroyer	-	-	P	P
Nymphon megalops Sars	-	-	-	P
Nymphon robustum Bell	-	-	P	P

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Nymphon rubrum Hodge	-	P	-	-
Nymphon serratum Sars	P	P	P	P
Nymphon stromi Kroyer	-	-	P	P
Pseudopallene circularis (Goodsir)	-	P	P	P
Pseudopallene spinipes (Fabricius)	-	-	P	-
ARTHROPODA: Tanaidacea				
Leptognathia longiremis (Lilljeborg)	P	-	-	-
Leptognathia sarsi	P	-	-	-
Sphyrapus anomalus G.O. Sars	P	-	-	-
Typhlotanais finmarchicus G.O. Sars	P	-	-	-
ASCHELMINTHES: Nematoda				
nematode	P	P	P	P
BRACHIOPODA				
Atretia gnomon	P	P	P	P
Hemithiris psittacea (Gmelin)	P	P	P	P
BRYOZOA				
Alcyonidium gelatinosum (Linnaeus)	P	P	P	-
Bidenkapia spitzbergensis (Bidenkap)	-	-	P	P
Bugula simpliciformis Osburn	-	P	-	-
Caberea ellisii (Fleming)	-	P	P	-
Callopora craticula (Alder)	-	P	P	-
Callopora lineata (Linnaeus)	-	[illegible]	P	P
Callopora whiteavesi Norman	-	P	-	-
Carbasea carbasea (Ellis and Solander)	-	P	-	-
Cauloramphus cymbaeformis (Hincks)	-	P	P	-
Celleporella (Hippothoa) hyalina (Linnaeus)	-	P	-	-
Celleporina surcularis (Packard)	-	P	P	P
Celleporina ventricosa (Lorenz)	-	P	P	P
Cheilopora sincera (Smitt)	-	-	P	P
Copidozoum smitti (Kluge)	-	-	P	-
Cribrilina annulata (Fabricius)	-	-	P	P
Cribrilina punctata (Hassall)	-	P	-	-
Crisia sp.	-	P	-	-
Cylindroporella tubulosa (Norman)	P	-	P	-
Cystisella elegantula (d' Orbigny)	-	P	P	-
Cystisella saccata (Busk)	P	P	P	P
Dendrobeania murrayana (Johnston)	-	P	P	P
Diplosolen obelia (Johnston)	-	P	P	P
Doryporella spathulifera (Smitt)	-	-	P	-
Electra arctica (Borg)	P	-	P	-
Escharella abyssicola (Norman)	-	-	P	-
Escharella connectens (Ridley)	-	-	P	-
Escharella immersa (Fleming)	-	-	P	-
Escharella thompsoni (Kluge)	-	-	P	-
Escharella ventricosa (Hassall)	-	P	P	P
Escharoides jacksoni (Waters)	-	P	P	P
Eucratea loricata (Linnaeus)	-	P	P	P
Gemmellaria loricata (van Beneden)	P	-	-	-
Harmeria scutulata (Busk)	-	-	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Hincksina nigrans (Hincks)	-	P	P	P
Hincksipora spinulifera (Hincks)	-	-	P	-
Hippoporella hippopus (Smitt)	P	-	P	P
Hippoporina cancellata (Smitt)	-	-	P	-
Hippoporina propinqua (Smitt)	P	P	P	P
Hippoporina reticulatopunctata (Hincks)	-	-	P	-
Hippothoa divaricata (Lamouroux)	-	P	-	-
Hippothoa expansa Dawson	-	P	P	-
Hippothoa hyalina (Linnaeus)	-	-	P	P
Idmonea atlantica Johnston	-	-	P	P
Kinetoskias arborescens Danielssen	P	-	P	-
Lepraliella contigua (Smitt)	-	-	P	-
Lichenopora hispida (Fleming)	-	-	P	-
Lichenopora verrucaria (Fabricius)	-	P	P	-
Membranipora serrulata (Busk)	-	P	P	P
Membraniporella crassicosta Hincks	-	-	P	-
Microporella ciliata (Pallas)	-	-	P	-
Microporina articulata (Fabricius)	-	-	P	P
Myriapora coarctica (M. Sars)	-	-	P	-
Myriapora subgracila (d' Orbigny)	-	P	P	P
Myriozoella plana (Dawson)	P	P	P	P
Parasmittina jeffreysi (Norman)	P	-	P	P
Phidolopora elongata (Smitt)	-	-	P	P
Porella acutirostris Smitt	-	-	P	P
Porella compressa (Sowerby)	-	P	P	P
Porella concinna (Busk)	-	P	P	-
Porella minuta Norman	-	-	P	-
Porella smitti Kluge	P	P	P	-
Porella struma (Norman)	-	P	P	-
Posterula sarsi (Smitt)	-	P	P	P
Pseudoflustra solida (Stimpson)	-	P	P	P
Reginella spitzbergensis (Norman)	-	-	P	-
Rhamphostomella bilaminata (Hincks)	-	-	P	-
Rhamphostomella costata Lorenz	-	P	P	P
Rhamphostomella hincksi Nordgaard	-	-	P	P
Rhamphostomella ovata (Smitt)	-	P	P	P
Schismopora nodulosa (Lorenz)	-	-	P	P
Schizomavella auriculata (Hassall)	-	-	P	-
Schizomavella porifera (Smitt)	-	-	P	-
Schizoporella obesa (Waters)	-	-	P	-
Schizoporella stylifera (Levinsen)	-	-	P	P
Scrupocellaria scabra (van Beneden)	P	P	P	P
Securiflustra securifrons (Pallas)	P	P	P	P
Smittina groenlandica (Norman)	-	-	P	-
Smittina majuscula (Smitt)	-	P	P	-
Smittina mucronata (Smitt)	-	-	P	-
Smittina porifera (Smitt)	-	P	-	-
Smittina rigida (Lorenz)	-	-	P	-
Smittina trispinosa (Verrill)	-	P	-	-
Stephanosella biaperta (Michelin)	-	-	P	-
Stomachetosella cruenta (Busk)	P	-	P	-
Stomachetosella limbata (Lorenz)	-	-	P	-
Stomachetosella sinuosa (Busk)	-	-	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Tegella arctica (d'Orbigny)	-	-	P	P
Tegella armifera (Hincks)	-	P	P	-
Terminoflustra membranaceotruncata (Smitt)	-	P	P	P
Tricellaria gracilis (van Beneden)	-	P	P	-
Tricellaria peachi (Busk)	P	P	P	P
Tricellaria ternata (Ellis and Solander)	-	-	P	P
Tubulipora sp.	-	P	-	-
Umbonula arctica (M. Sars)	-	-	P	P
CHAETOGNATHA				
Eukrohnia hamata Mobius	-	P	P	-
Sagitta elegans Verrill	P	P	P	-
Sagitta elegans arctica	-	P	P	-
Sagitta maxima	P	-	-	-
CHORDATA: UROCHORDATA: Ascidiacea				
Aplidium glabrum Verrill	-	P	P	P
Ascidia callosa Stimpson	P	P	P	P
Ascidia obliqua Alder	P	-	-	-
Ascidia prunum O.F. Muller	-	P	P	P
Boltenia echinata (Linnaeus)	P	P	P	P
Boltenia ovifera (Linnaeus)	P	P	P	P
Botrylloides aureum Sars	-	-	P	P
Bostichobranchus pilularis	-	P	-	-
Chelyosoma macleayanum	-	-	P	-
Ciona intestinalis	P	-	-	P
Cnemidocarpa finmarkiensis (Kiaer)	-	-	P	P
Cnemidocarpa mollis	P	-	-	-
Cnemidocarpa rhizopus (Redikorzev)	P	P	P	-
Dendrodoa aggregata (Rathke)	P	P	P	P
Dendrodoa grossularia (van Beneden)	-	-	P	-
Didemnum albidum (Verrill)	-	P	P	P
Distaplia clavata (Sars)	-	-	P	-
Halocynthia pyriformis (Rathke)	-	P	P	P
Kukenthalia borealis (Boldschaldt)	-	-	P	-
Lissoclinum aureum (Verrill)	-	-	-	P
Molgula griffithsi (MacLeay)	P	P	P	P
Molgula retortiformis (Verrill)	-	P	P	-
Molgula septentrionalis	P	-	-	-
Molgula siphonalis (Sars)	P	P	P	P
Pelonaia corrugata Goodsir and Forbes	P	-	P	P
Polycitor vitreus (Sars)	-	-	P	P
Rhizomolgula globularis (Pallas)	P	-	P	P
Styela coriacea (Alder and Hancock)	P	P	P	P
Styela rustica (Linnaeus)	P	P	P	P
Synoicum pulmonaria (Ellis and Solander)	-	P	P	P
CHORDATA: UROCHORDATA: Larvacea				
Fritillaria borealis Lohmann	P	P	-	P
Fritillaria sp.	-	-	P	-
Oikopleura labradoriensis Lohmann	P	-	-	-
Oikopleura vanhoeffeni Lohmann	P	P	-	P
Oikopleura sp.	-	-	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
CNIDARIA: Anthozoa				
Actinauge borealis	P	-	-	-
Actinauge rugosa	P	-	-	-
Actinostola groenlandica	-	P	-	-
Actinostola spetsbergensis	P	P	P	P
Allantactis parasitica	P	P	-	-
Bicidiopsis arctica	P	-	-	-
Bunodactis stella	P	P	-	-
Campanularia sp.	-	P	-	-
Drifa glomerata	-	-	P	P
Gersemia rubiformis Pallas	P	P	P	-
Halcampa arctica	-	-	P	P
Hippopodius hippopus	-	P	-	-
Hormathia digitata	-	-	P	-
Hormathia nodosa	-	P	P	P
Metridium senile	-	-	-	P
Stomphia coccinea	-	P	P	P
Tealia felina	P	P	P	P
Tealiopsis stella	P	-	-	-
CNIDARIA: Hydrozoa				
Abietinaria abietina	-	-	P	-
Aeginopsis laurenti (Brandt)	P	P	P	-
Aglantha digitale (O.F. Muller)	P	P	P	-
Aurelia aurita (Linneaus)	P	-	-	-
Bougainvillia sp.	P	-	-	-
Bougainvillia principis	-	P	-	-
Bougainvillia superciliaris (L. Agassiz)	-	P	P	-
Calycella syringa (Linnaeus)	P	P	P	P
Campanularia groenlandica	-	-	P	-
Campanularia integra	P	P	P	P
Campanularia speciosa	-	-	P	-
Campanularia verticillata (Linnaeus)	-	P	P	P
Campanularia volubilis (Linnaeus)	P	P	P	P
Catablema vesicaria A. Agassiz	-	-	P	-
Coryne hincksi	P	-	-	-
Coryne pusilla	-	P	P	P
Cuspidella humilis	P	-	P	P
Cuspidella procumbens	-	P	-	P
Diphasia pulchra Nutting	P	P	-	-
Eudendrium arbusculum	-	P	P	-
Eudendrium capillare	-	P	P	-
Eudendrium rameum (Pallas)	P	P	-	P
Eudendrium tenellum	-	P	P	-
Eudendrium vaginatum Allman	-	-	P	-
Euphysa sp.	-	-	P	-
Euphysa flammea	-	P	-	-
Filellum serpens	-	P	P	P
Gonothyraea loveni	P	-	P	P
Grammaria abietina	-	-	P	P
Grammaria immersa	-	-	-	P
Halecium curvicaule	-	-	P	P

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Halecium groenlandicum	P	P	P	-
Halecium labrosum	-	P	P	-
Halecium minutum	P	P	P	P
Halecium muricatum	-	P	P	P
Halecium speciosum	-	P	P	P
Halecium undulatum	P	P	P	-
Halitholus cirratus Hartlaub	-	P	P	-
Halitholus pauper Hartlaub	P	-	P	-
Hartlaubella gelatinosa (Pallas)	-	P	-	-
Hebella pocillum Hincks	-	P	-	-
Hybocodon prolifer L. Agassiz	-	-	P	-
Hydractina carica	-	-	-	P
Lafoea fruticosa	-	-	P	-
Lafoea gracillima (Alder)	P	P	P	P
Lafoeina maxima	-	P	P	-
Leuckartiara brevicornis ? Murbach & Shearer	-	-	P	-
Leuckartiara nobilis	-	P	-	-
Monocoryne gigantea	-	-	P	-
Myriothela phrygia	-	-	P	-
Obelia geniculata	-	-	P	-
Obelia sp.	P	-	-	-
Opercularella lacerata (Johnston)	-	P	-	P
Phialidium languidum	-	P	-	-
Posterula sarsi	-	-	-	P
Ptychogastria polaris Allmann	-	-	P	-
Rathkea octopunctata (M. Sars)	P	-	P	-
Rhizorhagium roseum	P	P	-	-
Sarsia eximia (Allman)	P	-	-	-
Sarsia princeps (Haeckel)	P	P	P	-
Sarsia tubulosa L. Agassiz	-	P	P	-
Sertularella pinnata	-	-	P	-
Sertularella polyzonias (Linnaeus)	P	P	P	P
Sertularella tenella	-	P	-	-
Sertularella tricuspidata (Alder)	P	P	P	-
Sertularia mirabilis	-	P	P	-
Sertularia plumosa	-	-	P	-
Sertularia robusta	-	P	P	P
Sertularia schmidti	P	P	P	P
Sertularia similis	P	P	P	P
Sertularia tenera	-	P	-	P
Staurophaura mertensi	P	-	-	-
Stegopoma plicatile (G.O. Sars)	P	P	-	-
Tetrapoma quadridentatum	-	P	P	-
Thuiaria carica	-	P	-	-
Thuiaria lonchitis	-	P	-	-
Thuiaria thuja	-	-	P	P
Tima formosa	-	P	-	-
CNIDARIA: Scyphozoa				
Cyanea capillata	-	P	-	-
Cyanea sp.	P	-	P	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
CTENOPHORA				
Beroe cucumis Fabricius	-	P	P	-
Mertensia ovum (Fabricius)	-	P	P	-
Mertensia sp.	P	-	-	-
Pleurobrachia pileus	-	P	-	-
ECHINODERMATA: Asteroidea				
Asterias vulgaris	-	P	-	-
Ctenodiscus crispatus (Retzius)	P	P	P	P
Henricia eschrichti (Muller and Troschel)	P	P	P	P
Henricia sanguinolenta (O.F. Muller)	-	P	P	P
Henricia scabrior (Mikhailovskii)	-	-	P	P
Hippasteria phrygiana	-	P	-	-
Icasterias panopla (Stuxberg)	P	-	-	-
Leptasterias floccosa (Levinsen)	-	P	-	-
Leptasterias groenlandica (Steenstrup)	P	P	P	P
Leptasterias polaris (Muller and Troschel)	P	P	P	P
Lophaster furcifer (Duben and Koren)	P	P	P	P
Poraniomorpha tumida (Stuxberg)	-	P	-	-
Pteraster militaris (O.F. Muller)	P	P	P	P
Pteraster obscurus (Perrier)	-	P	P	P
Pteraster pulvillus M. Sars	-	P	P	P
Solaster endeca (Linnaeus)	-	P	P	P
Solaster papposus (Linnaeus)	P	P	P	P
Solaster syrtensis Verrill	-	-	P	P
Stephanasterias albula (Stimpson)	-	P	P	P
Urasterias lincki (Muller and Troschel)	P	P	P	-
ECHINODERMATA: Crinoidea				
Heliometra glacialis (Leach)	P	P	P	P
ECHINODERMATA: Echinoidea				
Strongylocentrotus droebachiensis (O.F. Muller)	P	P	P	P
ECHINODERMATA: Holothuroidea				
Chiridata sp.	-	P	-	-
Cucumaria calcigera	P	-	-	P
Cucumaria frondosa	P	P	P	P
Myriotrochus rinki Steenstrup	P	P	P	P
Psolus fabricii (Duben and Koren)	-	P	P	P
Psolus peronii Bell	-	P	-	-
Psolus phantapus (Strussenfelt)	P	P	P	P
Thyonidium sp.	P	-	P	P
ECHINODERMATA: Ophiuroidea				
Amphipholis squamata (Delle Chiaje)	-	-	P	-
Amphiura fragilis Verrill	-	-	P	-
Amphiura sundevalli (Muller and Troschel)	-	P	P	P
Gorgonocephalus arcticus Leach	P	P	P	P
Gorgonocephalus eucnemis	P	P	-	-
Ophiacantha bidentata (Retzius)	P	P	P	P
Ophiocten sericeum (Forbes)	P	P	P	P
Ophiomusium lymani	-	P	-	-

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Ophiopholis aculeata (Linnaeus)	P	P	P	P
Ophiopus arcticus	P	P	P	P
Ophiura robusta (Ayres)	P	P	P	P
Ophiura sarsi Lutken	P	P	P	P
Stegophiura nodosa Lutken	P	-	P	P
MOLLUSCA: Cephalopoda				
Gonatus fabricii (Lichtenstein)	-	-	P	-
Rossia molleri	-	-	-	P
Rossia palpebrosa	-	-	P	-
MOLLUSCA: Gastropoda				
Acanthodoris pilosa	-	P	-	-
Acirsa costulata (Mighels and Adams)	-	X	-	-
Acmaea rubella	-	-	P	P
Acmaea testudinalis (O.F. Muller)	P	P	P	-
Acteocina sp.	-	P	-	-
Admete couthouyi (Jay)	P	P	-	P
Aladaria harvardiensis	-	P	-	-
Alvania cf. *mighelsi*	-	-	P	-
Aquilonaria turneri Dall	-	X	-	-
Beringius ossiani	-	-	-	P
Boreotrophon clathratus Linnaeus	-	X	-	P
Boreotrophon fabricii (Moller)	-	P	P	P
Boreotrophon truncatus (Strom)	P	-	P	P
Buccinum ciliatum (Fabricius)	-	P	P	-
Buccinum cyaneum	-	-	P	P
Buccinum finmarkianum	-	-	P	-
Buccinum glaciale Linnaeus	-	P	P	P
Buccinum hydrophanum Hancock	P	P	P	P
Buccinum micropoma	-	-	-	P
Buccinum moerchi Friele	-	-	P	-
Buccinum scalariforme	P	P	P	P
Buccinum sericatum	-	-	P	P
Buccinum tenu	-	P	-	-
Buccinum totteni	P	-	P	P
Buccinum undatum	-	-	P	P
Buccinum undatum belcheri	-	P	-	P
Capulacmaea radiata	-	-	P	P
Cingula arenaria	-	-	P	-
Cingula castanea (Moller)	-	-	P	-
Cingula cf. *globula*	-	-	P	-
Cingula sp.	X	-	-	-
Clione limacina Phipps	P	P	P	-
Colus islandicus (Gmelin)	P	X	-	P
Colus pubescens (Verrill)	-	P	-	P
Colus spitzbergensis	-	-	-	P
Colus tortuosus (Reeve)	-	-	P	P
Coryphella salmonacea	-	-	P	-
Cylichna alba (Brown)	P	P	P	P
Cylichna magna	P	-	-	-
Cylichna occulta	P	-	P	P
Dendronotus frondosus	-	-	-	P

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Diaphana minuta	-	-	-	P
Gyraulus parvus	-	P	-	-
Gyraulus sp.	X	-	-	-
Haminoea solitaria (Say)	-	X	-	-
Hydrobia minuta (Totten)	P	-	-	-
Lacuna glacialis	-	-	-	P
Lepeta caeca (O.F. Muller)	P	P	P	P
Littorina obtusata (Linnaeus)	P	P	P	-
Littorina saxatilis (Olivi)	P	P	P	P
Limacina helicina	-	P	P	-
Lunatia pallida (Broderip and Sowerby)	P	P	P	P
Margarites costalis (Gould)	P	P	P	P
Margarites groenlandicus (Gmelin)	P	P	P	-
Margarites helicinus (Phipps)	P	P	P	P
Margarites olivaceus (Brown)	P	P	P	P
Margarites umbilicalis (Broderip and Sowerby)	P	P	P	P
Margarites vahli (Moller)	-	P	-	P
Marsenina glabra	-	-	P	-
Mohnia sp.	-	P	-	-
Natica clausa Broderip and Sowerby	-	P	-	P
Neptunea despecta (Linnaeus)	-	P	P	P
Oenopota arctica	-	-	-	P
Oenopota bicarinata (Couthouy)	-	P	P	P
Oenopota sp. (cf. *cinerea*)	-	-	P	-
Oenopota declivis (Loven)	-	-	P	P
Oenopota incisula (Verrill)	P	P	-	P
Oenopota pyramidalis (Strom)	-	X	P	P
Oenopota reticulata	P	-	P	-
Oenopota turricula (Montagu)	-	P	P	P
Omalyogyra sp.	-	P	-	-
Onchidiopsis glacialis	-	-	P	P
Onchidiopsis kingmaruensis	-	-	-	P
Philine finmarchia	P	-	-	-
Philine lima	-	-	-	P
Plicifusus kroeyeri (Moller)	P	P	P	-
Propebela sp.	-	P	-	-
Puncturella noachina (Linnaeus)	-	-	P	P
Retusa obtusa	P	-	P	-
Solariella obscura	-	P	-	-
Spiratella helicina (Phipps)	P	P	P	-
Stobilops labyrinthica	-	P	-	-
Tachyrhynchus erosus (Couthouy)	-	X	-	-
Tachyrhynchus reticulatus (Mighels and Adams)	P	P	P	P
Trichotropis bicarinata	-	-	-	P
Trichotropis borealis (Broderip and Sowerby)	P	X	P	P
Trichotropis conica	-	-	P	P
Trophonopsis sp.	-	P	-	-
Vallonia gracilicosta	-	P	-	-
Velutina plicatilis	-	-	-	P
Velutina undata	P	-	P	P
Velutina velutina (O.F. Muller)	P	P	P	P
Volutopsius norvegicus	-	-	P	P

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
MOLLUSCA: Pelecypoda				
Astarte arctica (Gray)	-	-	P	-
Astarte borealis (Schumacher)	P	P	P	P
Astarte crenata crenata (Gray)	P	P	-	-
Astarte crenata crebricostata (McAndrews and Forbes)	P	P	-	-
Astarte elliptica (Brown)	-	-	P	-
Astarte montagui Dillwyn	P	P	P	P
Astarte striata (Leach)	P	P	P	P
Astarte warhami Hancock	P	P	P	P
Axinopsida orbiculata (G.O. Sars)	P	P	P	P
Bathyarca glacialis (Gray)	P	P	P	-
Chlamys islandica (Muller)	P	P	P	-
Clinocardium ciliatum (Fabricius)	P	P	P	P
Congeria conradi	-	P	-	-
Crenella decussata (Montagu)	P	P	P	-
Crenella faba (O.F. Muller)	P	P	P	P
Crenella glandula	-	P	-	-
Cuspidaria glacialis (G.O. Sars)	-	X	-	-
Cuspidaria subtorta (G.O. Sars)	P	-	-	-
Cyclocardia borealis (Conrad)	-	-	P	-
Cyrtodaria kurriana Dunker	-	P	P	-
Dacridium vitreum (Moller)	P	-	-	-
Delectopecten greenlandicus (Sowerby)	P	P	P	P
Entodesma sp.	P	-	-	-
Hiatella arctica (Linnaeus)	P	P	P	P
Limatula hyperborea (Jensen)	-	-	P	-
Limatula subauriculata (Smith)	-	-	P	-
Lyonsia arenosa (Moller)	P	X	P	P
Macoma balthica (Linnaeus)	P	P	P	-
Macoma calcarea (Gmelin)	P	P	P	P
Macoma loveni (Steenstrup)	P	-	P	P
Macoma moesta (Deshayes)	P	P	P	P
Macoma torelli (Steenstrup)	P	-	P	P
Musculus corrugatus (Stimpson)	P	P	P	P
Musculus discors (Linnaeus)	P	P	P	P
Musculus niger (Gray)	P	P	P	P
Mya arenaria	-	P	-	-
Mya pseudoarenaria Schlesch	P	-	-	-
Mya truncata Linnaeus	P	P	P	P
Mytilus edulis Linnaeus	P	P	P	-
Nucula belloti Adams	P	P	P	P
Nucula delphinodonta Mighels and Adams	P	-	P	-
Nuculana minuta (Fabricius)	P	P	P	P
Nuculana pernula (O.F. Muller)	P	P	P	P
Nuculana tenuisulcata (Couthouy)	-	P	-	-
Pandora glacialis Leach	P	P	P	P
Periploma abyssorum Verrill	P	P	P	-
Pisidium casertaneum (Poli)	P	-	-	-
Portlandia arctica arctica (Gray)	P	P	-	P
Portlandia arctica portlandica (Hitchcock)	P	P	-	-
Portlandia arctica siliqua (Reeve)	-	-	-	P
Portlandia lenticula (Moller)	P	P	P	P
Serripes groenlandicus (Bruguiere)	P	P	P	P

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Sphaerium simile (Say)	X	-	-	-
Thracia devexa G.O. Sars	P	-	-	-
Thracia myopsis Moller	P	X	P	-
Thracia septentrionalis Jeffreys	P	-	-	-
Thyasira equalis Verrill and Bush	?	-	-	-
Thyasira flexuosa	-	P	-	-
Thyasira gouldi (Philippi)	P	P	P	P
Yoldia amygdalea Valenciennes	-	-	P	-
Yoldia hyperborea (Loven)	P	P	P	P
Yoldia myalis (Couthouy)	-	-	P	-
Yoldiella intermedia (M. Sars)	P	-	-	-
Yoldiella lucida Loven	-	-	P	-
MOLLUSCA: Polyplacophora				
Ischnochiton albus (Linnaeus)	P	P	P	P
Tonicella marmorea (Fabricius)	P	P	P	P
Tonicella blaneyi	-	P	-	-
MOLLUSCA: Scaphopoda				
Siphonodentalium lobatum (Sowerby)	-	P	-	-
NEMERTEA				
Nemerteans	P	P	P	P
Tubulanus sp.	-	P	-	-
PHORONIDA				
"horse shoe fan worm"	-	P	-	-
PORIFERA				
Biemna (?) sp.	P	-	-	-
Echinoclathria (?) sp.	-	-	P	-
Gellius varius	-	-	P	-
Grayella pyrula	-	-	P	-
Halichondria disparilis	-	-	P	-
Halichondria panicea	P	-	-	-
Halichondria sitiens	-	-	P	-
Haliclona ventilabrum	-	-	P	-
Hymeniacidon heliophila	-	P	-	-
Isodictya palmata	-	-	-	P
Leucandra sp.	P	-	-	-
Mycale lingua	-	-	P	-
Myxilla incrustans	-	-	P	-
Phakettia bowerbanki	P	-	-	-
Phakettia ventilabrum	P	-	-	-
Stelodoryx pluridentata	-	-	P	-
Suberites domocula ficus	P	-	-	-
Tetilla polyura	P	-	-	-
Tetilla sibirica	P	-	-	-
Tylodesma (?) sp.	P	-	-	-
PRIAPULIDA				
Halicryptus spinulosus	-	-	P	-
Priapulus caudatus (Linnaeus)	P	P	P	P

Species	James Bay (includes S.E. Hudson Bay)	Hudson Bay	Hudson Strait	Foxe Basin
Priapulus humanus Chamberlin	-	P	-	-
SIPUNCULA				
Golfingia eremita	-	-	P	-
Golfingia lilljeborgi	-	P	P	-
Golfingia margaritacea	-	P	P	P
Phascolion strombi	P	-	P	-
Phascolosoma hudsonianum Chamberlin	-	P	-	-
Themiste alutacea	-	P	-	-

[1] = probable identification

[2] = *Themisto* = *Parathemisto*: *T. compressa*, *T. gaudichaudi* and *T. gracipiles* may be synonymous.

Species Occurrence:

P = species occurrence reported in the published literature, or in unpublished consulting reports by Baker (1989, 1996), Baker et al. (1993, 1994), Byers (1993), Lawrence and Baker (1995), or Zrum (2000).

X = mollusc species records based on recently dead animals and/or empty shells only (Wagner 1968; Macpherson 1971). Lubinsky (1980) did not indicate whether some of her records were based on empty shells.

? = probable occurence in the James Bay marine region.

Organisms identified only to genus were only included where the genus was not otherwise reported from the region.

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APPENDIX 3 MARINE, ESTUARINE AND ANADROMOUS FISHES REPORTED FROM THE JAMES BAY, HUDSON BAY, AND HUDSON STRAIT MARINE REGIONS (SEE MAP FIGURE 1-1).

The James Bay marine region includes southeastern Hudson Bay (Figure 1-1). The table is organized phylogenetically following Nelson et al. (2004). Nomenclature also follows Nelson et al. (2004) except for a few rare or deep-sea species (*) where it follows Coad and Reist (2004). Symbols are explained, and references listed, at the end of Appendix 3 on page A-40.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
CLASS CHONDRICHTHYES: cartilaginous fishes						
Family Somniosidae: sleeper sharks						
Somniosus microcephalus (Block and Schneider, 1801)	Greenland Shark	M	M	M	Large, pelagic shark common in Hudson Strait. Anecdotal reports from Hudson Bay and Foxe Basin. May grow to 7 m total length and inhabit depths to at least 1200 m.	Harvested for skin, oil and meat in Greenland. By-catch in Baffin turbot fishery. Eats fish, seals, whales, and birds.
Family Rajidae: skates						
Amblyraja jenseni (Bigelow and Schroeder, 1950)	shorttail skate	-	-	M	Small skate found at depths of 640-2300 m at temperatures of 3-4°C. Reported from eastern Hudson Strait and Ungava Bay.	Reported infrequently in Canadian Atlantic waters. Eats planktonic crustaceans and small fishes (e.g., *Sebastes* spp.).
Amblyraja radiata (Donovan, 1808)	thorny skate	M	?	M	Medium-sized skate found on hard and soft bottoms at depths of 18-996 m. Has been captured near Kuujjuarapik.	By-catch in Atlantic commercial fisheries, used for fish meal. Eats benthic invertebrates and small fishes.
Bathyraja spinicauda (Jensen, 1914)	spinytail skate	-	-	M	Large, cold-water skate generally found at bottom temperatures of –1.5 to 3.3°C and depths below 185 m. Occurs in Ungava Bay	Infrequently reported from Canadian Atlantic waters. Eats capelin and thorny skate.
CLASS ACTINOPTERYGII: RAY-FINNED FISHES						
Family Acipenseridae: sturgeons						
Acipenser fulvescens Rafinesque, 1817	lake sturgeon	S	?	-	Benthic omnivore found in rivers that drain into southern Hudson and James bays. Enters estuaries in James Bay. Hydroelectric developments can alter spawning habitat. Juveniles and adults can tolerate salinities up to 15 ppt (=psu)(LeBreton and Beamish 1998).	Smoked and eaten by subsistence fishers.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Family Clupeidae: Herrings						
Clupea harengus Linnaeus, 1758	Atlantic herring	M	M	M	Small, primarily pelagic, schooling marine fish found inshore or offshore from surface to depths of 200m. Occurs in the Innuksuak and Maquatua river estuaries (Morin et al. 1980, 1982)	Canadian and World fisheries harvest herring for flesh, oil, and roe.
Family Cyprinidae: minnows						
Couesius plumbeus (Agassiz, 1850)	lake chub	S	?	-	Small, freshwater, pelagic fish present in mainland coastal river systems north to Little Whale River. Occasionally enters weak brackish waters.	Forage fish.
Notropis atherinoides Rafinesque, 1818	emerald shiner	?	S	-	Small, freshwater, pelagic fish present in the lower Churchill and Nelson rivers. Common in nearshore brackish water of the Nelson River estuary in summer (Baker 1989).	Forage fish.
Family Catostomidae: suckers						
Catostomous catostomous (Forster, 1773)	longnose sucker	S	S	S	Benthic, freshwater fish found in mainland drainages south of the Arctic Circle. Occasionally enters brackish coastal waters. Brackish nearshore waters of the Nelson River estuary are important summer feeding habitat for juveniles from the lower Nelson River (Baker 1989, 1990).	Harvested by subsistence fisheries—mainly for dog food.
Catostomous commersonii (Lacepède, 1803)	white sucker	S	?	-	Benthic, freshwater fish found in mainland drainages south of the Arctic Circle. Occasionally enters brackish coastal waters.	Harvested by subsistence fisheries—mainly for dog food.
Moxostoma macrolepidotum (Leseur, 1817)	shorthead redhorse	?	-	-	Benthic, freshwater fish found in mainland drainages of southern Hudson Bay and James Bay. Rarely enters brackish coastal waters.	Unknown.
Family Esocidae: pikes						
Esox lucius Linnaeus, 1758	northern pike	S (rare)	S (rare)	S (rare)	Freshwater, pelagic fish uncommon in drainages north of the treeline. Occasionally enters weak brackish waters.	Harvested by subsistence and sport fisheries.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Family Osmeridae: smelts						
Mallotus villosus (Müller, 1776)	capelin	B	B	B	Small pelagic marine fish of cold deep waters. Also found in brackish coastal waters. Locally and sporadically abundant in Hudson Bay; occurs in James Bay south to (51°53'N, 80°45'W) (Zalewski and Weir 1981) and in Richmond Gulf (Dutil and Power 1980). Capelins spawn along shoreline in the Belchers (M. Dunbar, pers. comm.). Larvae are abundant in summer in the Churchill, Nelson, and Great Whale estuaries (Ponton et al. 1993; Lawrence and Baker 1995; Zrum 2000).	Food for many species of fish, birds and marine mammals (Fleming and Newton 2003). Harvested by subsistence fisheries during spawning.
Osmerus mordax (Mitchill, 1814)	rainbow smelt	-	A (rare)	-	This small, pelagic, anadromous, schooling fish is a recent immigrant to Hudson Bay, having passed quickly down the Nelson River system and from there to the lower Churchill River via the coastal waters of Hudson Bay (D. Remnant, North/South cons. Ltd., Winniepg, pers. comm. 2003). Its spread may harm the quality of commercially harvested freshwater and anadromous species that prey upon it.	Eaten by northern pike in the lower Churchill and Nelson rivers (Zrum 1999; D. Remnant, North/South Cons. Inc, Winnipeg, pers. comm. 2003).
Family Salmonidae: whitefishes, grayling, salmons, trouts, and charrs						
Coregonus artedi Le Sueur, 1818	lake cisco	A	A	A	Pelagic, freshwater fish found in mainland drainages south of the Arctic Circle. Anadromous in James Bay where it can be abundant in eelgrass beds. Migrate along the Hudson Bay coast between the Churchill and Nelson rivers (Lawrence and Baker 1994).	Harvested for subsistence.
Coregonus clupeaformis (Mitchill, 1818)	lake whitefish	A	A	A	Pelagic, freshwater fish found in mainland drainages of the region. Occasionally enters brackish coastal waters in summer.	Harvested for subsistence.
Prosopium cylindraceum (Pennant, 1784)	round whitefish	A	A	A	Anadromous pelagic fish found in mainland drainages of the region and in the brackish coastal waters of eastern James Bay and southeastern Hudson Bay in summer. May be less common in brackish water along the southwest coast of Hudson Bay.	Harvested for subsistence.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Salmo salar Linnaeus, 1758	Atlantic salmon	D	D	D	Anadromous pelagic fish that winters at sea but returns to fresh water to spawn. Uncommon in the region but common in the Ungava Bay area—taken in Innuksuak River estuary (Morin et al. 1980).	Harvested as a by-catch of coastal fisheries except in Ungava Bay where it is harvested by subsistence, commercial, and sport fisheries.
Salvelinus alpinus (Linnaeus, 1758)	Arctic charr	A	A	A	Anadromous pelagic fish common in coastal waters of the region in summer. Uncommon in James Bay and along the southern coast of Hudson Bay.	Harvested in quantity by subsistence, commercial and sport fisheries. Economically and culturally important.
Salvelinus fontinalis (Mitchill, 1814)	brook trout	A	A	A	Anadromous, pelagic fish common in coastal waters of southern Hudson and James bays in summer. Rare north of Churchill or Povungnituk.	Harvested by subsistence and sport fisheries.
Salvelinus namaycush (Walbaum, 1792)	lake trout	S	S	S	Freshwater, pelagic fish common in mainland drainages north to Fury and Hecla Strait. Occasionally enters brackish coastal waters. Uncommon on Southampton Island (Stewart and Bernier 1984).	Harvested by subsistence, commercial and sport fisheries.
Thymallus arcticus (Pallas, 1776)	Arctic grayling	-	S?	S?	Pelagic, freshwater fish found in drainages along the west coast of Hudson Bay. May enter brackish waters of western Hudson Strait and Hudson Bay on rare occasions (Pfaff 1937; D. McGowan, DFO Winnipeg, pers. comm.).	Excellent sport fish.
Family Paralepididae: barracudinas						
Arctozenus risso (Bonaparte, 1840)	white barracudina	-	-	M	Small, pelagic, deepwater, marine fish eaten by cod in Ungava Bay. *Formerly known as Notolepis rissor kroeyeri* (Lutken, 1892) (Coad and Reist 2004).	Food for many larger predatory fishes and seals.
Family Balthylagidae: blacksmelts						
Bathylagus euryops Goode and Bean, 1896	goitre blacksmelt	-	-	M	Small deepwater pelagic fish. Generally found in the North Atlantic at depths of 548 to 1352 m.	Unknown.
Family Myctophidae: lanternfishes						
Benthosema glaciale (Reinhardt, 1837)	glacier lanternfish	-	-	M	Small mesopelagic marine fish that occurs from the surface to a depth of 503 m. Found in Ungava Bay and the North Atlantic.	Unknown.
Lampanyctus crocodilus (Risso, 1810)	jewel lanternfish	-	-	M	Small epipelagic to benthopelagic fish found from the surface to depths of 1000 m, eats zooplankton.	Unknown.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
**Lampanyctus macdonaldi* (Goode and Bean, 1896)	rakery lanternfish	-	-	M	Small mesopelagic marine fish found from the surface to depths of over 1000 m.	Eaten by cod in Ungava Bay.
**Notoscopelus kroeyerii* (Malm, 1861)	Krøyer's lanternfish	-	-	M	Small mesopelagic marine fish found from the surface to depths of over 1000 m.	Eaten by many commercially harvested fishes.
**Symbolophorus veranyi* (Moreau, 1868)	largescale lanternfish	-	-	M	Mesopelagic marine fish found from the surface at night to depths of over 800m during the day. Grows to 1.3 m. Found in Ungava Bay.	Eaten by swordfish.
Family Percopsidae: trout perches						
Percopsis omiscomaycus (Walbaum, 1792)	trout-perch	S	?	-	Small, freshwater, bottom feeder found in shallow mainland streams and lakes north to Little Whale River. Occasionally enters weak brackish water.	Eaten by predatory fishes and fish-eating birds.
Family Macrouridae: grenadiers						
Macrourus berglax Lacepède, 1801	roughhead grenadier	-	-	M	Pelagic, deep water, marine fish found along the coasts near the bottom at depths of 200 to 1000 m.	Eaten by cod.
Family Moridae: moras						
**Antimora rostrata* Günther, 1878	blue antimora (blue hake)	-	-	M	Small, mainly benthic, marine fish found at depths of 457 to 3277 m.	Unknown.
Family Phycidae: Phycid hakes						
**Gaidropsarus ensis* (Reinhardt, 1837)	threebeard rockling	-	-	M	Small, pelagic, marine fish that occurs to a depth of 1600 m.	Unknown.
Urophycis chesteri (Goode and Bean, 1878)	longfin hake	-	-	M	Small, deepwater, demersal, marine fish most abundant at depths of 300-450 m in temperatures of 1.6 to 9.7°C. Occurs in Ungava Bay.	By-catch of Atlantic commercial fisheries used for fish meal and oil. Eaten by Atlantic cod and white hake.
Family Gadidae: codfishes						
Arctogadus glacialis (Peters, 1872)	polar cod	-	M	M	Small, cryopelagic or epontic marine fish widely distributed in the Arctic. Occurs from the surface to depths of 930 m.	Important forage fish for many larger predatory fishes, seabirds, and marine mammals. Sometimes fished for subsistence.
Boreogadus saida (Lepechin, 1774)	Arctic cod	M	M	M	Small, pelagic, schooling, marine fish widely distributed in the Arctic. Locally and sporadically abundant. Larvae typically avoid the brackish water of the under-ice river plumes (Ponton and Fortier 1992; Ponton et al. 1993).	Important forage fish for many larger predatory fishes, seabirds, and marine mammals. Sometimes fished for subsistence.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Gadus morhua Linnaeus, 1758	Atlantic cod	-	-	M	Pelagic marine fish that can grow to 90 kg. Occurs from the surface to depths of 457 m.	Harvested by subsistence and commercial fisheries on a small scale within the region. Eaten by many predatory fishes and marine mammals.
Gadus ogac Richardson, 1836	Greenland cod	B	B	B	Demersal, non-schooling fish widespread in coastal inlets of the region where it is evenly distributed to a depth of 35 m (Mikhail and Welch 1989). Common in brackish estuaries of James Bay in winter. May spawn in estuaries (Morin et al. 1991). Eat capelin and benthic crustaceans.	Harvested by subsistence and commercial fisheries on a small scale within the region. Eaten by seals.
Lota lota (Linnaeus, 1758)	burbot	S	S	S	Freshwater omnivore that sometimes enters brackish estuaries. Larvae are present in weakly brackish water of the Great Whale River estuary in spring (Ponton et al. 1993).	Occasionally harvested for subsistence. The rich livers are prized by Inuit.
Family Gasterosteidae: sticklebacks						
Culaea inconstans (Kirtland, 1840)	brook stickleback	S	-	-	Small benthic or pelagic freshwater fish that occasionally enter weakly brackish estuaries.	Important forage, when abundant, for predatory fishes and fish-eating birds.
Gasterosteus aculeatus (Linnaeus, 1758)	threespine stickleback	A	A	A	Small, anadromous, benthic or pelagic fish that occasionally enter brackish coastal waters in summer. Not reported from the islands of northern Hudson Bay.	Important forage, when abundant, for predatory fishes and fish-eating birds.
Pungitius pungitius (Linnaeus, 1758)	ninespine stickleback	A	A	A	Small, anadromous benthic or pelagic fish that occasionally enter brackish coastal waters in summer. Not reported from Coats or Mansel islands.	Important forage, when abundant, for predatory fishes and fish-eating birds.
Family Scorpaenidae: scorpionfishes						
Sebastes mentella Travin, 1951	deepwater redfish	-	-	M	Marine fish weighing up to 8.5 kg. Benthic on rocky or muddy bottom during the day and pelagic at night.	Harvested commercially on the Atlantic coast. Eaten by large cod and halibut. Eat small pelagic fishes and invertebrates.
Sebastes norvegicus (Ascanius, 1772)	golden redfish	-	-	M	Marine fish weighing up to 8.5 kg. Benthic on rocky or muddy bottom during the day and pelagic at night. Usually found in water temperatures of 3-8°C at depths less than 290 m. Formerly *S. marinus*.	Harvested commercially on the Atlantic coast. Eaten by large cod and halibut. Eat small pelagic fishes and invertebrates.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Family Cottidae: sculpins						
Artediellus scaber Knipowitsch, 1907	rough hookear, hamecon	-	-	M	Small, benthic marine fish found in coastal regions and to depths of 290m.	Unknown.
Artediellus uncinatus (Reinhardt, 1835)	Arctic hookear sculpin	-	-	M	Small, benthic marine fish found in coastal regions and to depths of 400m.	Unknown.
Cottus cognatus Richardson, 1836	slimy sculpin	S	S	S	Small, benthic freshwater fish that inhabits cool stream or lake waters from near shore to a depth of 125 m. Occasionally enters brackish water.	Eaten by lake trout and northern pike.
Cottus ricei (Nelson, 1876)	spoonhead sculpin	S	S	-	Small, benthic freshwater fish that inhabits cool stream or lake waters from near shore to a depth of 135 m. Occasionally enters brackish water.	Eaten by lake trout and burbot.
Gymnocanthus tricuspis (Reinhardt, 1830)	Arctic staghorn sculpin	B	B	B	Small benthic marine fish found in cold waters from the intertidal zone to a depth of 174 m over rocky and/or sand bottom. Larvae are present in brackish water of the Great Whale River plume in spring and summer (Ponton et al. 1993).	Eaten by seals and seabirds.
Icelus bicornis (Reinhardt, 1840)	twohorn sculpin	M	M	M	Small benthic marine fish found in cold waters from the surface to a depth of 180 m.	Unknown.
Icelus spatula Gilbert and Burke, 1912	spatulate sculpin	M	M	M	Small, benthic marine fish found in Arctic waters from the shallows to 125 m depth.	Eaten by cod.
Myoxocephalus aenaeus (Mitchill, 1814)	grubby	-	-	B	Small, benthic marine fish found in coastal waters or estuaries. Abundant in eelgrass beds. Occur in depths of less than 95 m in protected areas. Found in eastern Hudson Strait and Ungava Bay.	Eaten by Atlantic cod.
Myoxocephalus octodecemspinusus (Mitchill, 1814)	longhorn sculpin	-	-	M	Small, benthic marine fish found in coastal waters. Moves into deeper water in winter, returns to shallows in spring. Preferred depth range 53-90 m. Occurs in eastern Hudson Strait.	Eats carbs and amphipods. Eaten by cormorants. By-catch of Atlantic commercial fishery.
Myoxocephalus quadricornis (Linnaeus, 1758)	fourhorn sculpin	E	E	E	Small, benthic marine fish found in Arctic coastal waters and brackish estuaries. Common in tidal pools and eelgrass beds, which may provide rearing habitat. Seldom descends below 20 m.	Eaten by may larger marine and anadromous fishes and by birds and marine mammals. Occasionally caught for sport, seldom eaten.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Myoxocephalus scorpioides (Fabricius, 1780)	Arctic sculpin	B	B	B	Small, benthic marine fish found in northern coastal waters over smooth or weedy bottom from shallows to 110 m depth—usually just below the intertidal zone.	Eaten by larger fishes and by seabirds.
Myoxocephalus scorpius (Linnaeus, 1758)	shorthorn sculpin	B	B	B	Benthic marine fish that grows to a length of 1 m. Found in cold northern coastal and shoal waters to a depth of 100 m. Spectacular breeding colouration.	Eaten by seabirds. Occasionally caught for sport, seldom eaten.
Triglops murrayi Günther, 1888	moustache sculpin	M	M	M	Small benthic marine fish usually found at depths of 18 to 110 m, but occurring to 320 m.	Eaten by cods and seabirds.
Triglops nybelini Jensen, 1944	bigeye sculpin	-	-	M	Small benthic marine fish found at depths of 30 to 930, usually in 200 to 600 m; occasionally inshore.	Eaten by seabirds.
Triglops pingelii Reinhardt, 1837	ribbed sculpin	M	M	M	Small benthic marine fish usually found at depths of 10 to 110 m, occurs to 930 m.	Eaten by cod and seabirds.
Family Agonidae: poachers						
Aspidophoroides monopterygius (Bloch, 1786)	alligatorfish	-	-	M	Small, slender, bottom-living marine fish usually found at depths of 18 to 192 m over sand or mud bottom. Occurs to a depth of 320 m.	Eaten by cod, haddock, and halibut.
Leptagonus decagonus[3] (Bloch and Schneider, 1801)	Alligator poacher	M	M	M	Small, slender, benthic marine fish found in Arctic waters at depths of 28 to 290 m over sand or mud bottom. Pelagic larvae.	Unknown.
Ulcina olriki (Lütken, 1876)	Atlantic alligatorfish	M	M	M	Small, slender, bottom-living marine fish usually found at depths of 18 to 110 m over a sand mud or rocky bottom. Formerly *Aspidophoroides olriki.*	Eaten by halibut.
Family Psychrolutidae: fathead sculpins						
Cottunculus microps Collett, 1875	polar sculpin	-	-	M	Small, benthic marine fish found at depths of 201-896 m in water temperatures of about 1.3-4°C. Occurs in Ungava Bay.	Unknown.
Family Cyclopteridae: lumpfishes						
**Cyclopteropsis jordani* Soldatov in Soldatov andPopov, 1929	smooth lumpfish	-	-	M	Marine fish reported form Ungava Bay (Hunter et al. 1984)	Unknown.
Cyclopterus lumpus Linnaeus, 1758	lumpfish	M	M	M	Largely benthic marine fish found on rocky bottom from near surface to 329 m. Grow to 9.5 kg. Move shoreward in April to spawn in shallower water and seaward in late autumn.	Eaten by seals, sperm whales, and Greenland shark. Harvested by the Atlantic commercial fisheries for roe and flesh.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Eumicrotremus derjugini Popov, 1926	leatherfin lumpsucker	-	M	M	Small, benthic marine fish found in Arctic waters at depths of 54 to 150 m on mud, gravel or stony bottom.	Eaten by cod and seabirds.
Eumicrotremus spinosus (Fabricius in Müller, 1776)	Atlantic spiny lumpsucker	M	M	M	Small, benthic marine fish found in Arctic waters on mud, gravel, or rocky bottom at depths of 5 to 82 m.	Eaten by cod and seabirds.
Family Liparidae: snailfishes						
Careproctus longipinnis Burke, 1912	longfin snailfish	-	-	M	Small, epibenthic marine fish found in deep waters to 800 m.	Unknown.
Careproctus reinhardti (Krøyer, 1862)	sea tadpole	M	M	M	Small, benthic, deep-sea fish found in Arctic waters down to 1250 m.	Unknown.
Liparis atlanticus (Jordan and Evermann, 1898)	Atlantic snailfish	-	-	M	Small benthic marine fish found in shallow inshore waters, including tidal pools, usually at depths less than 2 m. Spawn in intertidal zone.	Unknown.
Liparis fabricii Krøyer, 1847	gelatinous snailfish	M	M	M	Small, benthic and pelagic, marine fish found in Arctic waters, often over muddy waters, at depths of 40 to 600 m.	Eaten by Atlantic cod, seals, terns, and murres.
Liparis gibbus Bean, 1881	dusky snailfish	M	M	M	Small, largely benthic, marine fish found over rock, sand, and mud bottoms to a depth of 364 m, likely most common between 100 and 200 m.	Eaten by Atlantic cod.
Liparis tunicatus Reinhardt, 1837	kelp snailfish	M	M	M	Small, largely benthic, marine fish found in Arctic and Subarctic waters generally at depths of less than 50 m and associated with kelp, sometimes in tidal pools or attached to *Laminaria* fronds.	Eaten by seals.
Family Percidae: perch						
Sander vitreus (Mitchill, 1818)	walleye	S	-	-	Freshwater fish found in James Bay drainages. Occasionally enters brackish water. Formerly *Stizostedion vitreum*	Harvested by subsistence, sport and commercial fisheries.
Family Zoarcidae: eelpouts						
**Gymnelus barsukovi* Chernova, 1999	Barsukov's pout	-	-	M	Small, rare, benthic marine fish found in from the shallows to 51 m depth.	Unknown.
Gymnelus viridis (Fabricius, 1780)	fish doctor	-	M	M	Small, benthic marine fish that is common and widespread in Arctic coastal waters.	Eaten by cods and sculpins.
**Lycenchelys kolthoffi* Jensen, 1904	wolf eel	-	-	M	Small, benthic, marine fish.	Unknown.
Lycenchelys paxillus (Goode and Bean, 1879)	common wolf eel	-	-	M	Small, benthic, marine fish. Found on mud or sand at depths of 46 to 1097 m. Occurs in Ungava Bay.	Unknown.
Lycenchelys verrilli (Goode and Bean, 1877)	wolf eelpout	-	-	M	Small, benthic marine fish. Found at depths of 46 to 1097 m. Occurs in Ungava Bay.	Unknown.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Lycodes esmarkii Collett, 1875	greater eelpout	-	-	M	Small, benthic, marine fish found on mud bottoms at depths of 151 to 500 m in –0.4 to 5.0°C water. Occurs in Hudson Strait and Ungava Bay.	Unknown.
Lycodes lavalaei Vladykov and Tremblay, 1936	Newfoundland eelpout	-	-	M	Small, benthic marine fish. Found on mud, and mud and sand, bottoms at depths of 57 to 535 m. Occurs in Ungava Bay.	Unknown.
Lycodes mucosus Richardson, 1855	saddled eelpout	-	-	M	Small, benthic, marine fish found in coastal waters.	Unknown.
Lycodes pallidus Collett, 1879	pale eelpout	M	?	M	Small, benthic marine fish that occurs over mud bottoms from 11 to 1750 m.	Unknown.
Lycodes polaris (Sabine, 1824)	polar eelpout	-	-	M	Small, benthic marine fish found in coastal waters.	Unknown.
Lycodes reticulatus Reinhardt, 1835	Arctic eelpout	M	M	M	Small benthic marine fish found over mud bottoms at depths of 55 to 229 m. Reported from stations in mid-Hudson Bay.	Unknown.
Lycodes vahlii Reinhardt, 1831	checker eelpout	-	-	M	Small benthic marine fish found in depths of 201-600 m and in temperatures of 2.0 to 4.5°C. Occurs in eastern Hudson Strait and Ungava Bay	Unknown.
Family Stichaeidae: shannies						
Anisarchus medius[1] (Reinhardt, 1837)	stout eelblenny	M	M	M	Small benthic inshore marine fish found in Arctic seas over sandy-mud bottom at depths of 16 to 119 m.	Eaten by cod.
Eumesogrammus praecisus (Krøyer, 1837)	fourline snakeblenny	M	M	M	Small benthic marine fish found in inshore waters of Arctic seas to a depth of 400 m over mud and rock bottom.	Eaten by cod and seabirds.
Leptoclinus maculatus[1] (Fries, 1837)	daubed shanny	M	?	M	Small benthic inshore marine fish found in Arctic seas, usually on shoals, at depths of 2 to 91 m below low tide.	Eaten by seabirds and commercially harvested fishes.
Lumpenus fabricii (Reinhardt, 1836)	slender eelblenny	B	B	M	Small benthic inshore marine fish found in Arctic seas over rock bottom at depths of 3 to 183 m. Occasionally enters brackish estuaries.	Eaten by cod, charr, and seabirds.
Lumpenus lampretaeformis (Walbaum, 1792)	snake blenny	-	-	M	Small benthic marine fish found in shoal waters over muddy or hard bottom to 90 m below tide line.	Eaten by cod, Pollock, halibut, and other larger fishes.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Stichaeus punctatus (Fabricius, 1780)	Arctic shanny	B	B	B?	Small benthic marine fish found in inshore waters of Arctic seas over cobble or boulder bottom to a depth of 55 m. Larvae are present in brackish water of the Great Whale River plume in spring and summer (Ponton et al. 1993).	Eaten by cod, Greenland halibut and seabirds. Important link in the food web between crustacean zooplankton and polychaetes and the black guillemot (Keats et al. 1993)
Family Pholidae: gunnels						
Pholis fasciata (Bloch and Schneider, 1801)	banded gunnel	M	M	M	Small inshore marine fish found from the intertidal zone to a depth of 28 m; usually at or near bottom over rocky substrate.	Eaten by Arctic cod, sculpins, and seabirds.
Family Anarhichadidae: wolffishes						
Anarhichas lupus Linnaeus, 1758	Atlantic wolffish	-	-	M	Benthic marine fish lives in moderately deep water (5-350 m), over hard bottom. Grows to 19.5 kg.	Commercially harvested in Atlantic Canada. Eats mollusks, crabs, urchins, and starfish. Eaten by cod.
Anarhichas minor Olafsen, 1772	spotted wolffish	-	-	M	Benthic marine fish that usually occurs at depths of 50 to 475 m. Can grow to a length of 2 m.	Harvested in Greenland for meat and leather. Not harvested in this region. Eats mollusks, crabs, urchins, and starfish. Eaten by Greenland sharks and cods.
Family Ammodytidae: sand lances						
Ammodytes dubius Reinhardt, 1837	northern sand lance	B	B	B	Small bottom-dwelling marine fish found inshore or offshore on banks at depths less than 91 m over sand. They burrow into the sand when not schooling.	Important food for larger fishes, marine mammals, and seabirds.
Ammodytes hexapterus[2] Pallas, 1814	stout sand lance	B	B	B	Small bottom-dwelling marine fish usually found inshore or on offshore banks at depths of 6-20 m. They burrow into the sand when not schooling. Larvae are common in brackish water of the Nelson River estuary in June and early July (Baker 1996; Horne 1997).	Important forage fish.
Family Pleuronectidae: righteye flounders						
Hippoglossoides platessoides (Fabricius, 1780)	Canadian plaice	B	?	B	Benthic marine fish that can grow to 6 kg. Found on fine sand or soft mud bottom at depths of 36 to 713 m. Occasionally enter brackish water. most common at depths of 73 to 274 m.	Eaten by many larger predatory fishes.

Species Name		Marine Region			Occurrence	Importance
Latin	Common	James Bay	Hudson Bay	Hudson Strait		
Reinhardtius hippoglossoides (Walbaum, 1792)	Greenland halibut (turbot)	-	?	M	Benthic marine fish that can grow to 25 kg. Found on soft bottoms, mostly between the depths of 200 to 600 m but sometimes to 1600 m. Undertake extensive migrations.	Eaten by many larger predatory fishes, seals, belugas, and narwhals. Commercially harvested in Hudson and Davis straits and along the Atlantic coast. eat many smaller commercially harvested fishes.
	COUNT:	53	49	89		

[1] Some authors place these species in the genus *Lumpenus*.

[2] Scott and Scott (1988) consider *Ammodytes hexapterus* and *A. americanus* to be synonymous and use the latter name to refer to the species.

[3] Some authors place *Leptagonus decagonus* in the genus *Agonus*.

* deep-sea species where nomenclature follows Coad and Reist (2004).

Species Occurrence:

Species listed have been reported in the published literature, from reliable grey literature, or are listed in National Museum of Natural Sciences (NMNS), Ottawa, or Royal Ontario Museum (ROM), Toronto, collections. Letter codings identify habitat use by each species:

M	marine species that do not frequent brackish estuaries or enter fresh water.
B	marine species that use brackish estuaries on a seasonal basis, often for nursery grounds.
E	estuarine species that can live in brackish water throughout their lives.
D	diadromous species that spawn in freshwater but can winter in salt water.
A	anadromous species that spawn and winter in fresh water but enter coastal marine waters in summer to feed.
S	semi-anadromous species that are primarily freshwater but occasionally enter weakly brackish water.
?	that may occur in the marine region as they have been collected from adjacent marine regions or, in the case of freshwater species that enter brackish coastal waters, from coastal drainages. A question mark has also been used to indicate uncertainty in the habitat coding (e.g., *Stichaeus punctatus* in Hudson Strait are coded B? as they occur in the strait but their presence in brackish water, while likely based on other areas, has not been confirmed)

References:

General area - many species: Vladykov 1933, 1934; Dunbar 1970: Scott and Crossman 1973; Lee et al. 1980; Hunter et al. 1984; Crossman and McAllister 1986; McAllister et al. 1987; Scott and Scott 1988; Coad and Reist 2004; ROM; NMNS.

General area - few species: Manning 1942; McAllister 1963a+b; McPhail 1961, 1963; Lindsey 1964; Khan and Quadri 1971; Coad 1973, 1974, 1983; Salonius 1973; McAllister and Aniskowicz 1976; Able and McAllister 1980; Johnson 1980; Martin and Olver 1980; Power 1980.

James Bay and southeastern Hudson Bay: Cox 1921; Dymond 1933; Edwards 1961; McAllister 1964; Hunter 1968; Dadswell 1974; Hunter et al. 1976; Greendale and Hunter 1978; Magnin and Clement 1979; Dutil and Power 1980; Morin et al. 1980, 1981, 1982; Simard et al. 1980; Zalewski and Weir 1981; Lambert and Dodson 1982; Lejeune and Shooner 1982; Ochman and Dodson 1982; St.-Arsenault et al. 1982; Dodson et al. 1985; Morin and Dodson 1986; Kemp et al. 1989; Lambert and Dodson 1990a+b; SEBJ 1990; Doyon et al. 1991; Drolet et al. 1991; Ponton and Fortier 1992; Ponton et al. 1993; Lalumière et al. 1994; Whoriskey et al. 1994.

Hudson Bay: Bean 1881; Dymond 1933; Walters 1953; Hunter 1968; Cowan 1972; Gaboury 1980; Morin and Dodson 1986; Baker 1989, 1990; Mikhail and Welch 1989; Baker et al. 1994; Lawrence and Baker 1995; Baker 1996; Horne 1997; Horne and Bretcher 1998; Zrum 1999, 2000; Stewart and Watkinson 2004; D. Remnant, pers. comm. 2003.

Hudson Strait: Richardson 1855; Turner 1885; Johansen 1927a-c; Henn 1932; Pfaff 1937; Hildebrand 1939; Dunbar 1947, 1952; Dunbar and Hildebrand 1952; Kennedy 1953; Tuck and Squires 1955; Templeman 1963; Patriquin 1967; Boulva 1972; Stewart and Bernier 1983, 1988; Sutcliffe et al. 1983; Gaston et al. 1985; Sopuck 1987; Taggart et al. 1989; Hudon 1990; Gaston et al. 2003.

APPENDIX 4 BIRD SPECIES THAT USE THE SHORELINES AND WATERS OF JAMES BAY AND HUDSON BAY (SEE EXPLANATORY NOTES BELOW).

Footnotes and symbol explanations are located at the end of Appendix 4 on page A-45, reference citations on page A-46.

SPECIES NAME		EASTERN HUDSON BAY			JAMES BAY		WESTERN HUDSON BAY			NORTHERN ISLANDS
Common	Latin	Northern Quebec	Hudson Bay Arc	Belcher Islands	Eastern	Western	Ontario	Manitoba	Nunavut mainland	
Family Gaviidae: Loons										
red-throated loon	*Gavia stellata* (Pontoppidan, 1763)	C +	C +	C +	U +	U +	U +	U +	C +	C +
Pacific loon	*G. pacifica* (Lawrence)	U +	U ?	C +	U +	U +	U +	C +	C +	C +
common loon	*G. immer* (Brünnich)	U +	C +	C +	C +	C +	U +	R +	U +	R ?
yellow-billed loon	*G. adamsii* (Gray)							R -	R -	
Family Podicipedidae: Grebes										
pied-billed grebe	*Podilymbus podiceps* (Linnaeus)					R +		R +		
horned grebe	*Podiceps auritus* (Linnaeus)				R -	U ?	R +	R +		
Family Procellariidae: Fulmars										
northern fulmar	*Fulmarus glacialis* (Linnaeus)					R -				R -
Family Hydrobatidae: Storm-petrels										
Leach's storm-petrel	*Oceanodroma leucorhoa* (Viellot)		R -							
Family Pelecanidae: Pelicans										
American white pelican	*Pelecanus erythrorhynchos* Gmelin				R -			R -		
Family Sulidae: Gannets										
northern gannet	*Sula bassanus* (Linnaeus)					R -		R -		
Family Phalacrocoracidae: Cormorants										
double crested cormorant[3]	*Phalacrocorax auritus* (Lesson)				U +			U -		
Family Ardeidae: Herons and Bitterns										
American bittern	*Botaurus lentiginosus* (Rackett)		R -		C +	C +	U +	R +		
great blue heron	*Ardea herodias* Linnaeus				R -	U ?				R -
snowy egret	*Egretta thula* (Molina)					R -				
little blue heron	*E. caerulea* (Linnaeus)							R -		
tricolor heron	*E. tricolor* (Müller)							R -		
black-crowned night heron	*Nycticorax nycticorax* (Linnaeus)							R -		
Family Anatidae: Geese, Swans, and Ducks										
greater white-fronted goose	*Anser albifrons* (Scopoli)		U -		R ?	U -		R -	U +	R -
snow goose[4]	*Chen caerulescens* (Linnaeus)	U +	C -	C -	C -	C +	C +	C +	C +	C +
Ross's goose	*C. rossii* (Cassin)				U -	U +	R +	C +	U +	U +
Canada goose	*Branta canadensis* (Linnaeus)	C +	C +	C +	C +	C +	C +	C +	C +	C +

SPECIES NAME		EASTERN HUDSON BAY			JAMES BAY		WESTERN HUDSON BAY			NORTHERN ISLANDS
Common	Latin	Northern Quebec	Hudson Bay Arc	Belcher Islands	Eastern	Western	Ontario	Manitoba	Nunavut mainland	
brant	*B. bernicla* (Linnaeus)	U -	C -	U -	C -	C -	U -	U -	U -	C +
trumpeter swan	*Cygnus buccinator* Richardson							R -		
tundra swan	*C. columbianus* (Ord)	U +	U +	U +	R -	U +	U +	C +	U +	C +
gadwall	*Anas strepera* Linnaeus				R -	R ?		R ?		
Eurasian widgeon	*A. penelope* Linnaeus							R -		
American widgeon (baldpate)	*A. americana* Gmelin		R -		U +	C +	C +	U +	R +	R -
American black duck	*A. rubripes* Brewster		C +	U -	C +	C +	C +	C ?	R -	
mallard	*A. platyrhynchos* Linnaeus		U -		C +	C +	C +	U +	U +	R -
blue winged teal	*A. discors* Linnaeus				U +	C +	U +	U +		
northern shoveler	*A. souchet* Linnaeus				R -	C +	U +	U +		R -
northern pintail	*A. acuta* Linnaeus	C +	C +	C +	C +	C +	C +	C +	C +	C +
green-winged teal	*A. crecca* Linnaeus		U +	R -	C +	C +	C +	C +	U +	U -
canvasback	*Aythya valisineria* (Wilson)							R +		
redhead	*A. americana* (Eyton)							R -		
ring-necked duck	*A. collaris* (Donovan)				U +	U +	R +	R +		
greater scaup	*A. mariia* (Linnaeus)		U +		U +	C +	C +	C +	U +	R -
lesser scaup	*A. affinis* (Eyton)				C +	C +	U +	R +	R -	
king eider	*Somateria spectabilis* (Linnaeus)	U +	U -	U +	U +	U +	U +	U +	U +	C +
common eider[5]	*S. mollissima* (Linnaeus)	C +	C +	C +	C +	C +	C +	C +	C +	C +
harlequin duck[6]	*Histrionicus histrionicus* (Linnaeus)	R ?	U +	R -	R ?	R -		R -		
surf scoter	*Melanitta perspicillata* (Linnaeus)	U -	C -	C -	C +	C -	C +	U +		
white-winged scoter	*M. fusca* (Linnaeus)	U -	C ?	C -	C +	C -	U ?	C +	U +	R -
black scoter (common scoter)	*M. nigra* (Linnaeus)	R -	C -	U -	C -	C -	C +	C +		R -
long-tailed duck (oldsquaw)	*Clangula hyemalis* (Linnaeus)	C +	C +	C +	C +	U +	C +	C +	C +	C +
bufflehead	*Bucephala albeola* (Linnaeus)					R -	R +	R +		R -
common goldeneye	*B. clangula* (Linnaeus)	R -	C ?	C -	C +	C +	U +	C +	R +	R -
Barrow's goldeneye	*B. islandica* (Gmelin)	R ?	R ?			R -		R -		
hooded merganser	*Lophodytes cucullatus* (Linnaeus)				R -	R ?		R -		
common merganser	*Mergus merganser* Linnaeus	C -	C -	C +	C ?	C ?	U +	U -		
red-breasted merganser	*M. serrator* Linnaeus	U +	U +	U ?	C +	C +	C +	C +	C +	U ?
ruddy duck	*Oxyura jamaicensis* (Gmelin)							R -		R -
Family Accipiteridae: Ospreys, Eagles, Hawks, and Allies										
osprey	*Pandion haliaetus* (Linnaeus)		R +		U +	U +	U +	R +		
bald eagle	*Haliaeetus leucocephalus* (Linnaeus)		R -		R -	R -	R -	U +		
northern harrier (marsh hawk)	*Circus cyaneus* (Linnaeus)		U -		C ?	C +	U +	U +		
northern goshawk	*Accipter gentilis* (Wilson)		R ?		R ?	R +				
sharp-shinned hawk	*A. striatus* Vieillot				R +	U +		R -		

SPECIES NAME		EASTERN HUDSON BAY			JAMES BAY		WESTERN HUDSON BAY			NORTHERN ISLANDS
Common	Latin	Northern Quebec	Hudson Bay Arc	Belcher Islands	Eastern	Western	Ontario	Manitoba	Nunavut mainland	
rough-legged hawk	*Buteo lapopus* (Gmelin)		U +	U +	U +	U +		U +	U +	U ?
golden eagle	*Aquila chrysaetos* (Linnaeus)		R +	R +	R +	R +	R +	R -		
Family Falconidae: Falcons										
merlin	*Falco columbarius* Linnaeus		U +		U +	C +	U +	U +	U +	R -
peregrine falcon[7]	*F. peregrinus* Tunstall	R +	R +	U +	R ?	R -	R ?	R +	C +	R +
gyrfalcon	*F. rusticolus* Linnaeus	U +		R -	R -			R -	R +	U +
prairie falcon	*F. mexicanus* Schlegel							R -		
Family Rallidae: Rails, Gallinules, and Coots										
yellow rail[8]	*Coturnicops noveboracensis* (Gmelin)				C ?	C +	U +	U +		
sora	*Porzana carolina* (Linnaeus)		U +		C +	C +	R +	R +		
American coot	*Fulica americana* Gmelin					U ?		R +		
Family Gruidae: Cranes										
sandhill crane	*Grus canadensis* (Linnaeus)			U -	U +	C +	U +	R +	U +	U +
Family Charadriidae: Plovers										
black-bellied plover	*Pluvialis squatarola* (Linnaeus)	R -	U -	U -	U -	C -	R -	U -	R -	U +
American golden-plover	*P. dominica* (Muller)	R -	R -	U -	U -	C +	U +	C +	U +	C +
semipalmated plover	*Charadrius semipalmatus* Bonaparte	C +	C +	C +	C +	C +	C +	C +	C +	C +
killdeer	*C. vociferus* Linnaeus				U +	C +	U +	U +		
Family Scolopacidae: Sandpipers, Phalaropes, and allies										
greater yellowlegs	*Tringa melanoleuca* (Gmelin)	C -	C -	C -	C ?	C +	C +	C +		R -
lesser yellowlegs	*T. flavipes* (Gmelin)				C +	C +	C +	U +	U -	
solitary sandpiper	*T. solitaire* Wilson				U +	U +	U +	R +	R -	
spotted sandpiper	*Actitis macularia* (Linnaeus)		U +		C +	C +	C +	U +	R +	
whimbrel[9]	*Numenius phaeopus* (Linnaeus)		U -		U -	C +	C +	C +	C +	C ?
Hudsonian godwit[10]	*Limosa haemastica* (Linnaeus)		U -		U -	C +	C +	C +		R ?
marbled godwit	*L. fedoa* (Linnaeus)				U -	C +				
ruddy turnstone	*Arenaria interpres* (Linnaeus)	C -	U -	C -	C -	C -	C +	C -	U ?	C +
red knot[10]	*Calidris canutus* (Linnaeus)		U -	U -	U -	C -	C -	C -	R -	U +
sanderling	*C. alba* (Pallas)		U -	R -	U -	C -	C -	C -	C +	U +
semipalmated sandpiper	*C. pusilla* (Linnaeus)	C +	U +	C +	C +	C +	C +	C +	C +	C +
little stint	*C. minuta* (Leisler)					R -				
least sandpiper	*C. minutilla* (Vieillot)	U +	C +	R +	C +	C +	C +	C +	C +	R +
white-rumped sandpiper	*C. fuscicollis* (Vieillot)	C -	C -	C -	C -	C -	C -	C -	C +	C +
Baird's sandpiper	*C. bairdii* (Coues)		U -	U -	U -	U -	R -	U ?	U +	U +
pectoral sandpiper	*C. melanotos* (Vieillot)	C -	U -	U -	U -	C +	C +	U -	U +	U +

SPECIES NAME		EASTERN HUDSON BAY			JAMES BAY		WESTERN HUDSON BAY			NORTHERN ISLANDS
Common	Latin	Northern Quebec	Hudson Bay Arc	Belcher Islands	Eastern	Western	Ontario	Manitoba	Nunavut mainland	
purple sandpiper	*C. maritima* (Brunnich)		U +	C +	U +	U ?	R ?	R -	U +	U +
dunlin	*C. alpina* (Linnaeus)		U -	U -	C +	C +	C +	C +	U +	U +
stilt sandpiper	*C. himantopus* (Bonaparte)					U ?	U +	U +	R +	R -
buff-breasted sandpiper	*Tryngites subruficollis* (Vieillot)							U -	U -	R -
short-billed dowitcher	*Limnodromus griseus* (Gmelin)				U +	C +	U +	U +	R -	
Wilson's snipe	*Gallinago delicata* Ord		U +		C +	C +	C +	C +	R -	R -
Wilson's phalarope	*Phalaropus tricolor* (Vieillot)				R -	U +				
red-necked phalarope (or northern phalarope)	*P. lobatus* (Linnaeus)	C +	C +	C +	C +	C +	C +	C +	C +	R +
red phalarope	*P. fulicaria* (Linnaeus)	R ?				R -		R -	U +	C +
Family Laridae: Jaegers, Gulls, and Terns										
Pomeranian jaeger	*Stercorarius pomarinus* (Temminick)	U +	R +					R -	U -	U +
parasitic jaeger	*S. parasiticus* (Linnaeus)	C -	U -	U +	U -	U +	C +	C +	C +	C +
long-tailed jaeger	*S. longicaudus* Vieillot	C +	R +	U -		R -	U -	U -	U +	U +
laughing gull	*Larus atricilla* Linnaeus							R -		
Franklin's gull	*L. pixican* Wagler							R -		
little gull	*Larus minutus* Pallas					U +	R ?	R +		
black-headed gull	*L. ridibundus* Linnaeus							R -		
Bonaparte's gull	*L. philadelphia* (Ord)				C +	C +	U ?	C +		R -
mew gull	*L. canus* Linnaeus							R +		
ring-billed gull	*L. delawarensis* Ord		U ?		U +	U +				R -
California gull	*L. californicus* Lawrence					R -		R -		
herring gull	*L. argentatus* Pontoppidan	C -	C +	C +	C +	C +	C +	C +	C +	C +
Iceland gull	*L. glaucoides* Meyer	U +		R -		R -	R -	U -	U -	R +
lesser black-backed gull	*L. fuscus* Linnaeus							R -	R -	R -
glaucous -winged gull	*L. glaucescens* Naumann							R -		
glaucous gull	*L. hyperboreus* Gunnerus	C -	U +	C +	R -	R -	R ?	U -	C -	C +
great black-backed gull	*L. marinus* Linnaeus		R -				R -	R -	R -	R -
black-legged kittiwake	*Rissa tridactyle* (Linnaeus)							R -	R -	U -
Ross's gull[11]	*Rodostethia rosea* (MacGillivray)					R -		R +		
Sabine's gull	*Xema sabini* (Sabine)				R -	R -	R -	U -	U -	C +
ivory gull[12]	*Pagophila eburnea* (Phipps)		R -		R -	R -		R -		R -
Caspian tern	*Sterna caspia* Pallas					U +	R ?	R -		C +
common tern	*S. hirundo* Linnaeus				C +	C +				
Arctic tern	*S. parasisaea* Pontoppidan	C +	C +	C +	C +	U +	C +	C +	C +	C +
Forster's tern	*S. forsteri* Nuttall							R -		
white-winged tern	*Chlidonias leucopterus* (Temminck)							R -		

SPECIES NAME		EASTERN HUDSON BAY			JAMES BAY		WESTERN HUDSON BAY			NORTHERN ISLANDS
Common	Latin	Northern Quebec	Hudson Bay Arc	Belcher Islands	Eastern	Western	Ontario	Manitoba	Nunavut mainland	
black tern	*C. niger* (Linnaeus)				R -	U +		R ?		
Family Alcidae: Auks, Murres, and Puffins										
dovekie	*Alle alle* (Linnaeus)	R ?	R -	R -						U -
thick-billed murre	*Uria lomvia* (Linnaeus)	C +	C -	R -	U -				U -	
black guillemot	*Cepphus grylle* (Linnaeus)	C +	C +	C +	C +	U ?	U +	R ?	C +	C +
Family Strigidae: Typical owls										
snowy owl	*Nyctea scandiaca* (Linnaeus)	U +	U ?	C +	U -	U -	R -	U +	C +	C +
short-eared owl[12]	*Asio fla meus* (Pontoppidan)	R -	U +	R -	C +	C +	U +	U +	U +	R ?
Family Alcedinidae: Kingfishers										
belted kingfisher	*Ceryle alcyon* (Linnaeus)		R +		U +	U +	U +	R -		
Family Corvidae: Crows and Ravens										
American crow	*Corvus brachyrhynchos* Brehm				U +	U +	U +	U +		
common raven	*C. corax* Linnaeus	C +	C +	C +	C +	C +	C +	C +	U +	U +
Family Alaudidae: Larks										
horned lark	*Eremophila alpestris*	C +	C +	C +	C +	C +	C +	C +	C +	C +
Family Motacillidae: Pipits										
American pipit	*Anthus rubescens* (Tunstall)	C +	C +	C +	C +	C +	C +	C +	C +	C +
	Number of confirmed species:	47	73	54	93	105	82	121	69	74
	Number of confirmed breeding species:	27	36	27	53	67	63	68	49	43

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[1] **Occurrence** : C = Common, U = Uncommon, R = Rare.

[2] Species that breed in an area are marked (+). Those for which breeding is suspected but not proven are marked (?), and those for which breeding is neither known nor suspected are marked (-). Where the latter are common they are generally summering non-breeders or abundant transients.

[3] The only known breeding colony of double crested cormorant on Canada's arctic coast is located at Way Rock in southeastern James Bay.

[4] The Hudson Bay coasts support half the eastern arctic breeding population of the lesser snow goose *C. c. caerulescens* (Linnaeus).

[5] The Hudson Bay subspecies of the common eider inhabits the region year-round and is not found elsewhere.

[6] The Atlantic population of the harlequin duck is considered a population of "Special Concern" in Canada by COSEWIC.

[7] South of Rankin Inlet there is an exceptional breeding concentration of the tundra subspecies *F. p. tundrius* of peregrine falcon, considered a species of "special concern" in Canada (COSEWIC).

[8] The yellow rail is considered a species of "special concern" in Canada (COSEWIC)

[9] The region is one of two disjunct breeding areas for the whimbrel in Canada.

[10] The Ontario coast of James Bay is a major a major fall flyway and resting area for the Hudsonian godwit and red knot. The latter areas are of Critical International Importance to the well-being of both species (Morrison 1983). A significant fraction of the breeding range of the Hudsonian godwit is located along the coast of Hudson Bay.

[11] The only known mainland nesting site for Ross's gull, which is considered "Threatened" in Canada (COSEWIC) and breeds mainly in the high Arctic, is located at Churchill.

[12] The Ivory gull and shorteared owl are considered species of "special concern" in Canada (COSEWIC).

References and Personal Communications:

General area-all species: Shortt and Peters 1942; Snyder 1957; Cooch 1968; Abraham and Finney 1986; Godfrey 1986; Morrison and Gaston 1986; Alsop 2002.

General area-few species: Cooch 1954, 1961; MacInnes and Cooch 1963; Lumsden 1975, 1984a; Bellrose 1976; Hanson and Jones 1976; Boyd et al. 1982; Abraham and Finney 1986; Reed 1986; Reed and Erskine 1986.

Northern Quebec (Quebec coast of Hudson Bay north of Inukjuaq): Bell 1884; Manning 1946; Todd 1963; Heyland et al. 1970; Gaston et al. 1985; Birt and Cairns 1986; Chapdelaine et al. 1986; Gaston and Cooch 1986; Nakashima 1988; Nakashima and Murray 1988; A. Reed, formerly Env. Can., Quebec, pers. comm.).

Hudson Bay Arc (Quebec coast of Hudson Bay from James Bay to Inukjuaq): Manning 1946; Nakashima and Murray 1988; Menkens and Malecki 1991.

Belcher Islands: Twomey and Herrick 1942; Manning 1946, 1976; Freeman 1970a+b; Menkens and Malecki 1991; Gilchrist and Robertson 1999, 2000.

Eastern James Bay: East 1938; Shortt and Peters 1942; Savile 1950; Manning and Coates 1952; Manning and Macpherson 1952; Curtis 1973a+b, 1976; Ouellet and Bourget 1975; Curtis et al. 1976; Manning 1981; Berkes 1982; Ross 1983; Dignard et al. 1991.

Western James Bay: Lewis and Peters 1941; Hope and Shortt 1944; Manning 1952; Cooch 1961; Peck 1972; Curtis 1973a+b; Curtis et al. 1976; Morrison and Harrington 1979; Martini et al. 1980b; Thomas and Prevett 1982; Craven and Rusch 1983; Morrison 1983; Prevett et al. 1983; Ross 1983, 1984; Abraham 1984; Lumsden 1984b; Cadman et al. 1987; Gillespie et al. 1991; Menkens and Malecki 1991; OMNR 1991; Savard and Dupuis 1999.

Ontario (Hudson Bay coast): Peck 1972; Hanson and Jones 1976; Lumsden 1959, 1975,1984 a+b; Thomas and Prevett 1982; Ross 1982, 1983, 1984; Ross and North 1983; Cadman et al. 1987; Tacha et al. 1988).

Manitoba: Bell 1884; Taverner and Sutton 1934; Jehl and Smith 1970; Evans and McNichol 1972; Ryder and Cooke 1973; Lumsden 1975, 1984a; Cooke et al. 1975; Hanson and Jones 1976; Chartier and Cooke 1980; Thomas and Prevett 1982; Lane and Chartier 1983; Schmutz et al. 1983; McRae 1984; Davis et al. 1985; Reynolds 1986; Byrkjedal 1987, 1989; Moser and Rusch 1988, 1989; Tacha et al. 1988; Jehl 1996; MARC 2003; P. Taylor, Pinawa, MB, pers. comm. 1991).

Nunavut mainland: Bell 1884; Low 1906; Sutton 1931; Hohn 1950; Savile 1951; MacInnes 1962; Maher 1967; Allen and Hogg 1978; Kerbes 1982; MacInnes and Kerbes 1987; Court et al. 1988, 1989; Korol 1989; R. Bromley, GNWT, Yellowknife, pers. comm. 1991; R. Kerbes, Env. Can., Saskatoon, pers. comm. 1990; C. Schenk, pers. comm.; C. Machtans, Env. Can., Yellowknife, pers. comm. 2004).

Northern Islands (Southampton, Bencas, Coats, and Mansel islands—including areas north of the Hudson Bay marine ecosystem boundaries, and the Ottawa islands):

Southampton Island: Low 1906; Sutton 1932; Bray 1943; Parker and Ross 1973; Brown et al. 1985; Gaston and Decker 1985; Gaston et al. 1986; Reed et al. 1987; A. Reed, formerly Env. Can. Quebec, pers. comm. 1993; C. Machtans, Env. Can., Yellowknife, pers. comm. 2004).

Coats and Mansel islands: Manning 1949; Gaston 1982; Gaston and Cooch 1986; Gaston et al. 1986; Gaston and Ouellet 1997; C. Machtans,Env. Can. Yellowknife, pers. comm. 2004).

APPENDIX 5 SAMPLES FOR WHICH METALS WERE DETERMINED SHOWING GEOGRAPHIC COORDINATES, DEPTH (m) AND PROPORTIONS OF PARTICLES OF SIZE >2mm, SAND, SILT AND CLAY (FROM HENDERSON 1989).

Sample No.	Longitude	Latitude	Depth (m)	Larger than 2mm (%)	Sand (%)	Silt (%)	Clay (%)
65TH 0046	-84.66706	61.79018	179	4.29	7.33	54.37	38.3
65TH 0055	-86.71702	61.44817	225	0.10	2.52	34.36	63.12
65TH 0064	-88.71697	61.10117	195	7.18	7.57	83.07	9.35
65TH 0066	-89.15796	61.01816	157	10.74	17.98	59.52	22.50
65TH 0080	-91.40804	60.94816	108	16.34	15.36	54.01	30.59
65TH 0082	-91.35003	61.17817	115	11.79	54.73	31.94	13.34
65TH 0086	-91.23705	61.62617	143	0	2.36	73.23	24.41
65TH 0088	-91.20805	61.85618	130	0.18	3.70	77.22	19.08
65TH 0090	-91.15004	62.08519	113	11.47	27.08	51.74	21.18
65TH 0120	-91.95004	60.50615	122	8.58	12.13	59.06	28.81
65TH 0130	-93.30000	59.54813	62	48.81	50.52	41.10	8.38
65TH 0132	-92.73301	59.09012	77	7.67	16.46	52.02	31.52
65TH 0134	-92.65801	58.85612	75	21.84	9.21	60.35	30.44
65TH 0137	-92.25003	58.65609	70	10.02	54.99	39.32	5.69
65TH 0146	-91.20003	59.13112	102	5.00	24.48	44.57	30.95
65TH 0150	-90.35005	59.14813	137	0	2.29	47.65	50.06
65TH 0152	-89.39997	59.31512	128	10.72	38.09	29.80	32.09
65TH 0166	-87.06700	60.50615	197	0	1.83	32.64	65.54
65TH 0174	-87.54999	61.59018					
65TH 0178	-89.39996	62.24819	170	0	6.27	64.25	29.48
65TH 0180	-89.42497	62.51520	170	2.29	9.90	69.57	20.53
65TH 0186	-90.25007	62.99821	102	17.60	59.81	28.79	11.40
65TH 0191	-90.56706	62.51520	106	16.70	39.6	47.61	12.79
65TH 0218	-90.18807	63.29021	55	42.42	60.66	28.87	10.47
65TH 0224	-89.56697	61.73118	164	10.66	20.11	60.83	19.06
65TH 0226	-88.69999	62.06519	154	0	8.15	60.90	30.95
65TH 0228	-88.49998	61.44817	163				
65TH 0229	-87.20000	61.26484	178	0.17	0.50	64.89	34.61
65TH 0230	-87.89199	60.84816	200				
65TH 0232	-87.60001	60.58116	201				
65TH 0234	-87.23300	60.09014	210				
65TH 0236	-86.82502	59.68114	216				
65TH 0238	-86.85802	59.44013	210				
65TH 0244	-85.30003	59.56513	180				
65TH 0245	-84.92505	59.56513	144	11.49	13.58	25.30	61.12
65TH 0250	-84.55005	59.59813	154	0.23	11.70	57.58	30.72
65TH 0252	-83.56696	59.64813	135				
65TH 0254	-82.44998	59.65613	190				
65TH 0258	-82.15000	59.22313	140	11.35	31.40	27.65	40.95
65TH 0260	-82.15800	59.59813	152				

Sample No.	Longitude	Latitude	Depth (m)	Larger than 2mm (%)	Sand (%)	Silt (%)	Clay (%)
65TH 0268	-80.37503	60.09815	155				
65TH 0272A	-79.19657	60.07904	143	0	16.22	34.67	49.11
65TH 0272B	-79.19657	60.07904	143	0	1.78	49.32	48.90
65TH 0274	-78.83305	59.97314	128				
65TH 0280	-80.35002	60.60615	140				
65TH 0282	-80.91701	59.81514	159				
65TH 0284	-81.58300	59.79813	143				
65TH 0288	-82.36698	59.19813	148				
65TH 0290	-82.96698	59.24813	200	8.37	29.30	68.95	1.75
65TH 0292	-82.73297	59.54813	255	0.92	1.37	27.06	71.56
65TH 0296	-83.89997	59.28113	137	3.99	21.67	48.69	29.63
65TH 0300	-84.56705	59.19812	121	7.70	38.74	32.34	28.92
65TH 0302	-85.26705	59.54813	155				
65TH 0304	-86.35802	59.51813	199	0	1.45	43.82	54.73
65TH 0320	-91.76703	59.16512	106	7.64	21.38	57.36	21.26
65TH 0326	-91.76704	59.68114	140	0.92	1.58	61.89	36.53
65TH 0328	-91.76704	60.01014	132				
65TH 0330	-92.43303	59.99814	101	8.37	12.35	54.72	32.93
65TH 0332	-92.09202	60.18114	123				
65TH 0336	-90.44205	60.06514	157	0.15	1.06	41.41	57.53
65TH 0338	-89.74996	60.03115	134	16.65	36.40	36.75	26.62
65TH 0340	-89.11697	60.06014	150	1.00	12.77	39.15	48.08
65TH 0342	-88.77498	60.22615	146	19.01	28.68	27.82	43.5
65TH 0344	-88.78298	60.58115	161	7.05	16.08	52.33	31.6
65TH 0348	-89.06996	60.84016	155	0.48	18.80	55.34	25.85
65TH 0352	-87.35001	60.74815	201	1.44	21.59	14.71	63.70
65TH 0354	-86.64202	60.75616	212	4.12	12.34	30.11	57.55
65TH 0360	-85.68704	59.77613	180	0	0.84	69.27	29.89
65TH 0362	-85.54204	60.08115	183	0.14	2.26	81.99	15.75
65TH 0366	-86.06703	61.12617	249	0.20	1.26	80.75	17.99
65TH 0370	-86.60002	61.11816	220	1.46	2.21	30.53	67.26
65TH 0371	-86.33303	61.33117	220	10.54	34.77	50.78	14.45
65TH 0382	-87.80000	62.48520	118	20.30	31.42	48.20	20.38
65TH 0398	-81.97500	63.13121	223	41.60	12.36	52.83	34.81
65TH 0402	-81.80000	62.70821	205	0	6.09	71.45	22.47
65TH 0406	-80.53302	62.09819	137	0.22	6.32	40.70	52.98
65TH 0408A	-80.90000	61.78118	148	0	2.43	58.98	38.51
65TH 0410	-81.18701	61.82618	181	0.22	1.39	62.75	35.86
65TH 0412	-80.96702	62.11519	185	10.20	1.66	65.17	33.17
65TH 0418	-81.90000	61.81818	229	0.21	0.28	34.41	65.31
65TH 0420	-82.44198	61.74818	227	0.54	3.07	66.64	30.29
65TH 0426	-82.92497	61.73518	229	0.24	13.33	63.38	23.29
65TH 0434	-83.93296	60.77616	190	11.59	13.54	52.17	34.29

Sample No.	Longitude	Latitude	Depth (m)	Larger than 2mm (%)	Sand (%)	Silt (%)	Clay (%)
65TH 0436	-84.47005	60.99816	215				
65TH 0438	-84.48706	61.24017	210	1.04	3.82	47.15	49.03
65TH 0440	-83.94995	61.01517					
65TH 0444	-84.50005	60.49015		0	16.81	41.32	41.87
65TH 0448	-86.13303	59.95114					
65TH 0452	-84.53305	58.72112		0	54.79	26.63	18.58
65TH 0454	-84.43005	59.03113		0	50.37	30.16	19.47
65TH 0458	-83.63297	58.58611		0	7.51	34.58	57.91
65TH 0462	-81.97499	58.10111	150	14.29	35.96	23.33	40.71
65TH 0464	-81.95799	57.74810					
65TH 0466	-83.06698	57.60110		0	5.15	31.4	63.45
65TH 0468	-82.94198	57.91511		0	6.04	42.54	51.42
65TH 0470	-82.84198	57.24810	165	0	0.51	31.65	67.83
65TH 0474	-82.91698	56.75109		0	2.98	33.28	63.74
65TH 0480	-86.51702	57.96510		0	1.35	53.64	45.01
65TH 0482	-87.13301	58.00111	159	3.14	2.61	44.81	52.58
65TH 0484	-87.73700	58.07310		0.09	4.06	51.81	44.13
65TH 0486	-87.44200	58.22511	167	7.56	22.36	34.13	43.51
65TH 0488	-86.81702	58.28111		0	0.50	51.45	48.05
65TH 0490	-88.00000	57.99810		0	27.33	45.72	26.95
65TH 0498	-90.49505	57.99810					
65TH 0500	-91.08304	57.99811					
65TH 0502	-91.71702	57.98111	55	62.29	63.54	21.96	14.5
65TH 0508	-92.01703	58.85612	84	31.18	44.22	49.58	6.20
65TH 0514	-93.30001	59.24813	51	12.11	65.19	20.95	13.86
65TH 0523	-88.41698	63.33122	177	9.00	4.47	74.39	21.14
65TH 0538	-85.36705	62.04819	165	8.51	2.69	65.68	31.63
65TH 0548	-82.66699	61.34817	212	2.95	0.42	47.09	52.49
65TH 0550	-81.94998	61.34817	194	0	0.55	43.28	56.17
65TH 0560	-79.08304	60.99816	137	0.24	5.15	47.88	46.97
65TH 0566	-78.43306	61.76518	104	49.47	34.36	20.98	44.66

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APPENDIX 6 CONCENTRATIONS OF METALS IN SAMPLES OF CLAY-SIZE SEDIMENT FROM HUDSON BAY (DATA FROM HENDERSON 1989).

Sample No	As ppm	Cr ppm	Cu ppm	Pb ppm	Zn ppm	Al pct	Ca pct	Co ppm	Mg pct	Mn ppm	Fe pct	K pct	Ni ppm
65TH 0046	2	171	36	42	173	5.35	2.25	27	2.20	0.07	4.70	3.06	76
65TH 0055	2	169	40	38	203	7.71	1.59	30	2.84	0.09	5.45	3.41	83
65TH 0064	2	170	75	44	183	7.08	2.11	28	2.89	0.06	5.36	3.51	77
65TH 0066	2	205	47	41	182	6.71	1.99	27	2.92	0.05	5.17	3.41	76
65TH 0080	2	186	70	43	168	6.03	1.07	22	2.45	0.05	4.92	3.29	74
65TH 0082	2	164	37	36	157	6.58	1.10	21	2.70	0.05	4.96	3.26	79
65TH 0086	2	159	45	30	155	6.03	1.24	22	2.55	0.05	4.82	3.19	69
65TH 0088	2	158	36	30	151	6.19	1.25	21	2.50	0.05	4.70	3.00	67
65TH 0090	2	153	50	40	154	8.30	1.25	26	2.30	0.06	5.08	3.50	77
65TH 0120	2	133	68	32	147	5.42	1.03	19	2.36	0.05	4.50	3.14	64
65TH 0130	2	163	28	41	164	5.89	1.91	21	2.15	0.06	5.03	3.27	69
65TH 0132	2	169	170	40	178	6.38	1.49	20	2.36	0.05	4.63	3.32	68
65TH 0134	2	167	90	40	182	6.12	1.38	24	2.70	0.05	5.08	3.42	70
65TH 0137	2	168	58	37	170	5.76	1.65	23	2.61	0.06	5.17	3.18	80
65TH 0146	2	166	122	40	181	5.25	1.09	22	2.57	0.05	5.15	3.30	72
65TH 0150	2	164	56	38	159	5.71	1.24	21	2.46	0.05	4.76	3.30	68
65TH 0152	2	155	53	44	163	8.54	1.83	29	2.31	0.14	5.38	3.28	71
65TH 0166	2	119	38	37	168	5.24	1.46	35	2.33	0.45	4.95	3.17	85
65TH 0174	2	154	47	35	157	6.86	1.94	22	2.61	0.05	4.64	3.10	65
65TH 0178	2	123	59	31	135	6.93	2.02	16	2.62	0.04	4.17	2.68	56
65TH 0180	2	122	33	35	130	9.40	1.88	16	2.62	0.05	4.20	2.66	69
65TH 0186	2	164	33	41	175	5.73	1.49	23	2.51	0.06	4.92	3.07	77
65TH 0191	2	236	58	41	178	7.85	1.20	30	3.08	0.07	6.34	3.73	96
65TH 0218	2	99	22	32	112	6.08	2.14	13	2.16	0.05	3.34	2.26	51
65TH 0224	2	108	37	46	158	7.63	2.62	21	3.93	0.06	5.13	3.21	69
65TH 0226	2	157	84	43	177	5.76	2.77	26	2.49	0.05	4.92	3.55	71
65TH 0228	2	151	41	34	171	6.50	1.39	32	2.36	0.14	4.62	3.18	73
65TH 0229	2	120	33	34	133	6.68	2.02	18	2.3	0.04	4.09	2.72	55
65TH 0230	2	154	37	40	168	6.82	2.18	29	2.69	0.08	5.08	3.21	74
65TH 0232	2	148	39	44	188	8.27	2.08	28	3.86	0.10	5.73	3.36	77
65TH 0234	2	144	41	44	156	7.72	1.62	38	2.57	0.45	4.92	3.35	98
65TH 0236	2	150	39	55	166	8.90	1.58	37	2.38	0.42	4.84	3.41	103
65TH 0238	7	130	36	44	196	7.69	1.72	30	3.00	0.21	5.75	3.48	85
65TH 0244	17	142	31	51	159	7.68	2.19	47	2.88	0.51	5.60	3.51	86
65TH 0245	8	145	36	49	193	6.31	1.45	31	3.08	0.17	6.10	3.77	88
65TH 0250	10	141	34	43	184	6.88	1.57	31	2.99	0.17	5.87	3.84	85
65TH 0252	7	122	34	35	165	5.90	1.46	26	2.63	0.12	5.21	3.30	64

Sample No	As ppm	Cr ppm	Cu ppm	Pb ppm	Zn ppm	Al pct	Ca pct	Co ppm	Mg pct	Mn ppm	Fe pct	K pct	Ni ppm
65TH 0254	5	141	43	40	185	7.13	1.70	26	2.90	0.07	5.37	3.55	72
65TH 0258	10	135	29	36	174	6.24	1.45	25	2.66	0.06	5.08	3.39	66
65TH 0260	2	148	30	34	180	5.00	1.36	27	2.50	0.12	5.19	3.42	66
65TH 0268	2	112	24	34	140	6.35	4.20	14	2.25	0.04	3.90	2.15	58
65TH 0272A	2	152	35	30	170	5.83	1.33	30	2.40	0.07	4.55	3.13	71
65TH 0272B	2	157	35	39	166	6.10	1.55	27	2.77	0.08	5.77	3.63	76
65TH 0274	2	138	31	27	149	6.43	1.31	23	2.30	0.06	4.51	3.01	66
65TH 0280	2	150	36	32	161	5.67	1.70	26	2.74	0.07	4.92	3.16	69
65TH 0282	2	153	35	31	181	6.03	1.39	31	2.56	0.09	4.94	3.21	75
65TH 0284	5	142	33	32	188	5.64	1.41	27	2.58	0.06	4.85	3.43	71
65TH 0288	2	137	38	29	179	6.25	1.70	27	2.69	0.07	4.87	3.33	67
65TH 0290	5	159	33	41	196	6.71	1.46	33	2.83	0.16	5.76	3.78	77
65TH 0292	2	124	35	37	187	6.82	1.52	29	2.85	0.06	5.49	3.41	79
65TH 0296	2	162	39	55	185	5.72	1.49	34	3.12	0.16	5.90	3.53	88
65TH 0300	2	145	38	41	161	6.30	1.80	30	2.77	0.17	5.43	3.70	85
65TH 0302	7	137	49	39	168	5.72	1.59	27	2.69	0.10	6.30	3.53	75
65TH 0304	8	128	35	36	177	5.85	1.4	30	2.62	0.16	5.48	3.43	75
65TH 0320	2	167	38	36	161	5.81	1.05	21	2.65	0.06	5.13	3.34	70
65TH 0326	7	170	35	41	157	5.69	1.11	21	2.60	0.05	5.09	3.35	64
65TH 0328	6	183	70	81	158	5.94	1.17	22	2.68	0.05	4.91	3.38	65
65TH 0330	2	158	32	84	142	6.16	1.24	18	2.68	0.06	4.88	3.14	64
65TH 0332	2	173	43	37	159	5.90	1.12	22	2.83	0.06	5.36	3.33	66
65TH 0336	2	150	38	35	162	4.90	1.73	24	2.77	0.06	5.13	3.35	62
65TH 0338	5	156	28	52	167	6.23	1.76	28	2.97	0.07	5.82	3.20	64
65TH 0340	2	148	40	34	174	6.80	1.82	26	3.16	0.06	5.50	3.22	64
65TH 0342	5	153	36	40	165	6.70	1.86	30	3.10	0.12	5.83	3.32	65
65TH 0344	9	154	42	48	170	6.34	1.97	26	3.07	0.08	5.41	3.43	64
65TH 0348	2	161	39	38	164	5.11	1.56	25	2.64	0.05	4.55	2.96	67
65TH 0352	2	156	60	49	204	6.42	1.79	32	2.89	0.20	5.91	3.58	81
65TH 0354	2	146	38	47	173	6.75	2.02	33	2.82	0.22	5.93	3.43	78
65TH 0360	2	130	32	137	171	3.15	0.80	28	1.37	0.07	2.68	1.69	79
65TH 0362	7	140	37	52	168	6.79	1.47	53	2.65	1.00	5.65	3.52	107
65TH 0366	2	126	35	42	165	6.43	1.68	39	2.71	0.79	5.44	3.27	85
65TH 0370	9	150	50	44	191	6.46	1.69	30	2.80	0.10	5.23	3.43	86
65TH 0371	2	127	29	35	137	4.79	3.30	16	2.20	0.04	3.94	2.88	51
65TH 0382	2	112	38	38	120	7.30	5.54	15	3.31	0.04	3.29	2.54	54
65TH 0398	2	163	39	43	137	5.28	3.68	16	2.44	0.04	4.19	2.76	57
65TH 0402	2	166	36	44	150	4.95	3.22	19	2.36	0.05	4.50	3.00	58
65TH 0406	2	155	36	44	163	5.80	2.21	26	2.59	0.07	4.77	3.11	70

Sample No	As ppm	Cr ppm	Cu ppm	Pb ppm	Zn ppm	Al pct	Ca pct	Co ppm	Mg pct	Mn ppm	Fe pct	K pct	Ni ppm
65TH 0408A	2	139	31	42	143	5.06	3.40	20	2.44	0.05	4.66	2.91	59
65TH 0410	2	144	36	44	167	6.23	2.08	30	2.77	0.08	5.10	3.19	71
65TH 0412	2	145	34	92	159	6.28	2.33	26	2.7	0.06	4.79	3.00	67
65TH 0418	2	147	36	50	161	6.58	2.21	28	2.95	0.12	5.28	3.18	68
65TH 0420	2	153	36	49	157	5.97	2.26	26	2.76	0.08	4.85	3.09	67
65TH 0426	2	156	38	42	161	6.40	2.50	27	2.83	0.07	5.14	3.36	69
65TH 0434	11	148	36	45	164	6.63	1.63	31	2.64	0.21	5.44	3.49	83
65TH 0436	2	142	37	42	181	6.09	1.63	31	2.86	0.12	5.63	3.41	79
65TH 0438	2	143	38	48	175	5.95	1.79	28	2.71	0.07	5.06	3.36	78
65TH 0440	2	152	37	54	177	6.59	1.69	34	2.75	0.20	5.42	3.63	84
65TH 0444	2	129	35	48	155	5.98	1.49	39	2.41	0.35	4.53	3.61	96
65TH 0448	8	181	37	73	210	9.79	1.77	38	3.44	0.40	6.75	4.96	90
65TH 0452	2	155	34	58	109	6.42	1.21	38	2.25	0.29	4.74	3.93	99
65TH 0454	2	146	35	60	180	6.07	1.22	37	2.28	0.25	4.68	3.86	95
65TH 0458	2	127	36	50	170	6.43	0.99	38	2.26	0.27	4.96	3.86	89
65TH 0462	2	125	27	39	143	6.27	1.18	23	1.97	0.08	4.00	3.37	62
65TH 0464	2	152	32	49	160	6.52	1.20	27	2.18	0.06	4.39	3.71	73
65TH 0466	77	149	35	51	174	5.91	0.96	27	2.19	0.06	4.76	3.76	81
65TH 0468	2	145	31	50	172	5.67	0.89	27	2.18	0.05	4.61	3.81	76
65TH 0470	2	150	36	62	180	5.45	0.96	32	2.21	0.09	4.88	3.82	84
65TH 0474	2	170	37	45	182	8.89	1.48	26	2.71	0.07	5.89	3.74	80
65TH 0480	2	164	34	55	168	7.73	1.54	28	2.60	0.06	5.59	3.56	79
65TH 0482	2	175	38	59	181	7.45	1.21	29	2.58	0.06	5.31	3.69	79
65TH 0484	2	176	30	48	172	7.12	1.13	24	2.58	0.06	5.22	3.67	63
65TH 0486	2	160	35	51	179	7.65	2.67	31	2.24	0.07	5.52	3.78	82
65TH 0488	2	171	35	54	196	7.28	1.08	35	2.53	0.09	5.32	3.91	83
65TH 0490	2	166	35	50	174	7.12	1.18	26	2.57	0.06	5.15	3.79	74
65TH 0498	2	162	29	52	156	7.01	1.69	22	2.47	0.06	5.03	3.58	72
65TH 0500	2	174	35	55	156	7.40	1.54	21	2.41	0.05	4.78	3.42	73
65TH 0502	2	143	29	64	150	7.71	4.11	23	2.29	0.06	5.17	3.22	69
65TH 0508	9	274	47	87	227	7.75	2.09	30	3.92	0.08	7.50	3.66	97
65TH 0514	2	163	33	49	159	8.32	2.43	24	2.51	0.06	5.33	3.58	72
65TH 0523	2	124	29	31	121	6.86	3.31	15	2.33	0.04	3.67	2.78	52
65TH 0538	2	153	35	43	166	7.30	2.12	26	2.62	0.05	4.47	3.35	71
65TH 0548	2	161	37	46	179	7.92	1.93	31	2.85	0.08	5.12	3.48	79
65TH 0550	2	161	36	45	179	7.57	1.68	33	2.78	0.10	5.40	3.28	79
65TH 0560	2	155	28	37	150	6.60	1.54	24	2.55	0.07	4.87	3.48	60
65TH 0566	2	159	36	48	161	7.36	1.86	27	2.75	0.12	5.34	3.27	73

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APPENDIX 7 METAL PAIR CORRELATIONS (r) FOR HENDERSON (1989) DATA; p=PROBABILITY THAT CORRELATION IS BY CHANCE; n=NUMBER OF PAIRS.

		Depth	As	Cr	Cu	Pb	Zn	Al	Ca	Co	Mg	Mo	Mn	Fe	K	Ni
Depth	r	1.00														
	p	0.00														
	n	97														
As	r	0.07	1.00													
	p	0.52	0.00													
	n	97	114													
Cr	r	-0.27	0.00	1.00												
	p	0.01	0.98	0.00												
	n	97	114	114												
Cu	r	-0.25	-0.05	0.27	1.00											
	p	0.02	0.57	0.00	0.00											
	n	97	114	114	114											
Pb	r	0.01	0.07	0.25	-0.06	1.00										
	p	0.92	0.44	0.01	0.54	0.00										
	n	97	114	114	114	114										
Zn	r	0.16	0.13	0.46	0.19	0.19	1.00									
	p	0.11	0.18	0.00	0.04	0.04	0.00									
	n	97	114	114	114	114	114									
Al	r	0.04	-0.02	0.17	-0.06	0.00	0.15	1.00								
	p	0.72	0.85	0.07	0.52	0.99	0.12	0.00								
	n	97	114	114	114	114	114	114								
Ca	r	0.09	-0.12	-0.23	-0.13	-0.09	-0.36	0.10	1.00							
	p	0.36	0.20	0.02	0.17	0.33	0.00	0.27	0.00							
	n	97	114	114	114	114	114	114	114							
Co	r	0.39	0.11	0.09	-0.12	0.24	0.49	0.21	-0.33	1.00						
	p	0.00	0.22	0.36	0.21	0.01	0.00	0.03	0.00	0.00						
	n	97	114	114	114	114	114	114	114	114						
Mg	r	0.11	0.00	0.27	0.04	-0.05	0.40	0.41	0.16	0.15	1.00					
	p	0.28	0.99	0.00	0.68	0.60	0.00	0.00	0.10	0.10	0.00					
	n	97	114	114	114	114	114	114	114	114	114					
Mo	r	0.11	-0.05	-0.14	-0.03	-0.01	-0.13	0.14	-0.08	0.43	-0.12	1.00				
	p	0.29	0.59	0.14	0.75	0.91	0.18	0.14	0.41	0.00	0.20	0.00				
	n	97	114	114	114	114	114	114	114	114	114	114				
Mn	r	0.32	0.07	-0.17	-0.10	0.11	0.10	0.16	-0.12	0.76	0.06	0.67	1.00			
	p	0.00	0.49	0.07	0.27	0.23	0.29	0.08	0.21	0.00	0.52	0.00	0.00			
	n	97	114	114	114	114	114	114	114	114	114	114	114			
Fe	r	0.03	0.10	0.51	0.06	0.06	0.69	0.39	-0.24	0.50	0.65	-0.03	0.24	1.00		
	p	0.77	0.29	0.00	0.51	0.54	0.00	0.00	0.01	0.00	0.00	0.77	0.01	0.00		
	n	97	114	114	114	114	114	114	114	114	114	114	114	114		
K	r	0.02	0.19	0.40	0.06	0.06	0.56	0.38	-0.40	0.56	0.30	0.08	0.26	0.70	1.00	
	p	0.82	0.05	0.00	0.55	0.53	0.00	0.00	0.00	0.00	0.00	0.42	0.01	0.00	0.00	
	n	97	114	114	114	114	114	114	114	114	114	114	114	114	114	
Ni	r	0.19	0.13	0.28	0.01	0.32	0.52	0.30	-0.39	0.83	0.15	0.39	0.62	0.51	0.58	1.00
	p	0.06	0.17	0.00	0.91	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
	n	97	114	114	114	114	114	114	114	114	114	114	114	114	114	114

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APPENDIX 8 PAIR CORRELATIONS (r) FOR RADIONUCLIDES AND PARTICLE SIZES IN SEDIMENTS FROM THE AREA OF RANKIN INLET IN 1995; p=PROBABILITY THAT CORRELATION IS BY CHANCE; n=NUMBER OF PAIRS.

		Depth	Sand	Silt	Clay	U238	U234	Th232	Th230	Ra226	Po210	Cs137
Depth	r	1.00										
	p	0.00										
	n	25										
Sand	r	-0.59	1.00									
	p	0.00	0.00									
	n	25	25									
Silt	r	0.45	-0.78	1.00								
	p	0.02	0.00	0.00								
	n	25	25	25								
Clay	r	0.28	-0.44	-0.21	1.00							
	p	0.18	0.03	0.31	0.00							
	n	25	25	25	25							
U238	r	0.40	-0.76	0.51	0.46	1.00						
	p	0.05	0.00	0.01	0.02	0.00						
	n	25	25	25	25	25						
U234	r	0.42	-0.77	0.47	0.52	0.77	1.00					
	p	0.04	0.00	0.02	0.01	0.00	0.00					
	n	25	25	25	25	25	25					
Th232	r	0.22	-0.32	0.04	0.45	0.36	0.35	1.00				
	p	0.28	0.12	0.87	0.02	0.08	0.08	0.00				
	n	25	25	25	25	25	25	25				
Th230	r	0.25	-0.25	0.03	0.35	0.31	0.23	0.94	1.00			
	p	0.22	0.23	0.89	0.09	0.13	0.28	0.00	0.00			
	n	25	25	25	25	25	25	25	25			
Ra226	r	0.48	-0.51	0.37	0.26	0.42	0.55	0.39	0.29	1.00		
	p	0.02	0.01	0.07	0.22	0.04	0.00	0.06	0.17	0.00		
	n	24	24	24	24	24	24	24	24	24		
Po210	r	0.08	-0.18	0.24	-0.06	0.17	0.31	0.02	-0.06	0.01	1.00	
	p	0.69	0.39	0.25	0.76	0.42	0.13	0.91	0.76	0.97	0.00	
	n	25	25	25	25	25	25	25	25	24	25	
Cs137	r	-0.14	-0.46	0.08	0.30	0.48	0.52	0.13	0.22	-0.05	-0.17	1.00
	p	0.59	0.06	0.75	0.24	0.05	0.03	0.63	0.40	0.85	0.51	0.00
	n	17	17	17	17	17	17	17	17	17	17	17